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American Institute of Electrical Engineers in Convention at Niagara Falls, N.Y., June 25-28, 1907.

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PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

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Public Safety

FOLLOWING a succession of accidents to fast railway trains last winter, statements were made that the public demanded the highest possible speed. This might be modified by adding the words "consistent with safety." Another important requirement is the maintenance of the advertised schedule, so that the traveler may plan his journey with a reasonable possibility of making the necessary connections. There are many reasonable excuses for delay. An open drawbridge is one of them. The adoption of electricity as a motive power makes it feasible to utilize tunnels to a greater extent than has heretofore been desirable, and bridges will no doubt be superseded by them, where the traffic warrants the change. Every precaution is being taken to guard against disaster upon the many subterranean lines now in operation, as well as those which are to be installed in the near future, but there is well-founded apprehension that the people are confronted with the possibility of a frightful disaster, which human foresight cannot always guard against. Single lives are daily being sacrificed without attracting comment; but when a number are killed and wounded the accident becomes a catastrophe, and if due to carelessness or neglect there is at once an unreasonable clamor, which frequently passes away without leading to any important improvement in conditions. The electrical engineer is now an important factor in every branch of industrial progress. The makeshift policy of pioneer days has been supplanted with a demand for the best possible construction. As an industry develops, better methods are introduced, and the general interchange of ideas, the criticism of proposed departures from current practice, should lead to continual improvement. The convention season now passing has been unusually active. No epoch-making invention has been brought out, but every department of electrical industry has shown an advance that is in the direction of public convenience, economy, and safety.

Delegates Conference

ALTHOUGH there was an informal gathering at the Milwaukee Convention in 1906 of members interested in local organizations, and an interesting exchange of views, no advance preparations had been made, and the representation of the Sections was not as general as was the case at the Niagara Falls convention in June. With the coöperation of the Board of Directors, Chairman Spencer made a special effort to inform the officers of the

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Sections that they were entitled to representation by their chairmen, and an appropriation was made to meet the cost of transportation, The result was very gratifying, as over twenty officers and delegates were present; distant points being especially well represented. There has been a distinct growth in the number of original papers presented at local meetings, possibly due to a better understanding of the policy of the Institute in sending to the Sections advance copies of papers read at the New York meetings. These are intended more especially for use where local papers cannot be obtained, yet they are frequently abstracted at the meetings of many of the largest Sections, and valuable discussions have thus been elicited. The extraordinary development of the Schenectady Section was interestingly told by Mr. Rushmore. Through its extension of meeting privileges to non-members upon payment of a small fee, the Section has been self-supporting, and carries over a surplus of $773.58 to begin next season's work. It has been the opinion of many that the plan of local membership would check the legitimate growth of the Institute: this does not appear to be the result, judging from the increase of the Institute membership in Schenectady. The same argument might be used against the publication of Institute papers in the technical press, and with still greater force. The Institute is too well established to be weakened by the broad policy of permitting its light to penetrate into every nook and corner of industrial activity. In this way its work becomes known to the greatest number, and its influence and prosperity augmented accordingly.

Foreign Members

ALL Members and Associates, wherever located, will hereafter be required to pay the annual subscription of ten dollars and fifteen dollars, respectively, for the two grades. There has been a reduction in favor of foreign members since the foundation of the Institute, but experience shows that the cost of supplying them with printed matter has been greater than the same service to domestic members, while the average total expenditure *per capita* has been over ten dollars, or double the subscription of foreign Associates. Under these conditions ordinary business prudence seemed to offer no alternative, and as the matter could be adjusted only by an amendment to the Constitution, the change was recommended by the committee. It is believed that there will be no general objection to this departure, as the merits of the publications of the Institute are so generally appreciated, that no engineer of standing will care to dispense with them. In the case of members now on the list, the proposed change cannot go into effect until the first of May 1908. As foreign members were given an opportunity to vote upon this question, presumably the conditions were understood by them, as there were but ninety-five negative ballots recorded out of a total of about four hundred members who will be affected by the change.

BY vote of the Board of Directors the New York meetings will hereafter be held on the second, instead of the fourth Friday of every month. This change was made to avoid the holidays which occasionally have made it necessary to select dates either too near or distant from the last or following meeting. The first meeting for the year 1907-1908 will therefore be held in the auditorium of the Engineers' Building on Friday, October 11, 1907.

IT is gratifying indeed to record that during the last four months no less than 659 men interested in electrical engineering have availed themselves of the advantages and privileges attaching to associate membership in the Institute.

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Selenium Cells*

By R. A. L. Snyder.

The element selenium was discovered by Berzelius in 1817. It can be obtained in various forms and applied to many uses, although its peculiar properties have been generally understood for only about thirty-five years. In 1873 while experimenting with selenium as an ohmic resistance, Willoughby Smith discovered that the resistance of this metal was reduced by exposure to light. In using sticks of selenium as a resistance in an experimental telegraph circuit, he had trouble with the current varying; on investigating he found that when the cover to a box in which he had placed the selenium was closed, the current was less than with the box open. Further investigation showed that the electrical resistance of selenium varied with the amount of light falling upon it.

Siemens, in 1875, carried out some valuable investigations of the properties of selenium, and his experiments revealed much of the various forms that selenium assumes under different conditions. After being melted and quickly cooled, selenium assumes a translucent, vitreous formation, and upon being held to the light will have a dark-red color. While in this condition it is a dielectric and can be electrified by friction, like glass. If, however, the molten selenium is cooled slowly it will assume a gray crystalline formation, become opaque to light, and will then conduct electricity. According to the electromagnetic theory of light, it would not conduct electricity did it remain translucent, as it is a well-known fact that all conducting metals are opaque to light.

Alexander Graham Bell took advantage of this property of selenium to invent a wireless telephone. This instrument, known as the photophone, transmitted speech over a beam of light. From 1880 to 1881 Professor Bell with Sumner Tainter, took out six or more patents on the photophone and selenium cells. These patents cover practically all the now known properties of selenium. Improvements in cells since that time have dealt principally with their practical application to various purposes rather than to any scientific investigation and improvement in their properties.

The photophone consists of a transmitter for varying the intensity of a beam of light by means of sound waves impinging upon it, and a receiver for converting the light waves at a distant point back into sound waves. The transmitter consists of a glass disk, silvered to reflect a pencil of light focused on it from the sun or an arc lamp. This glass disk is used as a diaphragm, similar to that of an ordinary telephone transmitter, except that the rear side of it is made free to reflect the beam of light. Professor Bell successfully used for this purpose glass disks varying from 2 in. in diameter, and the thickness of ordinary paper, to 30 in. in diameter, and of proportionate thickness. The smaller disks gave the better results. The receiver consisted of a parabolic reflector with a selenium cell placed at its focus. In series with the cell was placed a battery and telephone receiver.

This instrument talks quite distinctly and has been used for transmitting sounds over a distance of 700 ft. Prescott states that the fundamental conception of the photophone dates from 1878, when, in lecturing before the Royal Institute, Professor Bell announced the possibility of hearing a shadow fall upon a piece of selenium included in a telephone circuit. The photophone, however, outgrew the particular electrical combination that suggested it; for not the least of the remarkable points in this research is the discovery that audible vibrations are set up in thin disks of almost every kind of material by merely throwing upon them an intermittent light. If a glass bulb filled with fine charged cork dust and connected with a flexible tube

*A paper presented at a meeting of the Pittsburg Section, March 12, 1907.

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be placed in the focus of the parabolic reflector of a photophone, the light waves will be converted into sound waves the same as with the selenium-cell battery and telephone receiver. The action of light on the burnt cork dust, however, is not the same as on the selenium. The sound from the burnt cork dust appears to come from sudden expansion of air in the bulb caused by the heat absorbed from the light striking the burnt cork. It requires very little energy to throw air into vibration, which is obvious when one stops to think of the number of cubic yards shaken by the song of so small an insect as a cricket. The burnt cork photophone does not transmit speech as well as it transmits music, and is known as the musical photophone in distinction from the selenium or articulating photophone.

It may be thought that the heat rays accompanying a light beam have a great effect in changing the resistance of the selenium cell, but this is not the case. If a filter of alum water be interposed between the source of light and the transmitter it will absorb the heat rays and allow the light to pass, but it does not reduce the effect on the selenium cell. In fact the light rays towards the ultra-violet end of the spectrum seem to have the most powerful effect.

After the speaking arc was discovered, it was not long before different inventors were trying its effect upon the selenium cell. Their efforts were naturally successful and Herr Rühmer, the German scientist, was able to transmit speech by means of light to a distance of 15 miles. He placed the speaking arc in the focus of a parabolic reflector and collected the rays in a distant receiver similar to Professor Bell's photophone.

Phonograph. Herr Ruhmer also photographed the sound waves from a speaking arc upon a celluloid film, and reproduced the sounds by passing the film between a source of light and a selenium cell in series with a battery and telephone receiver.

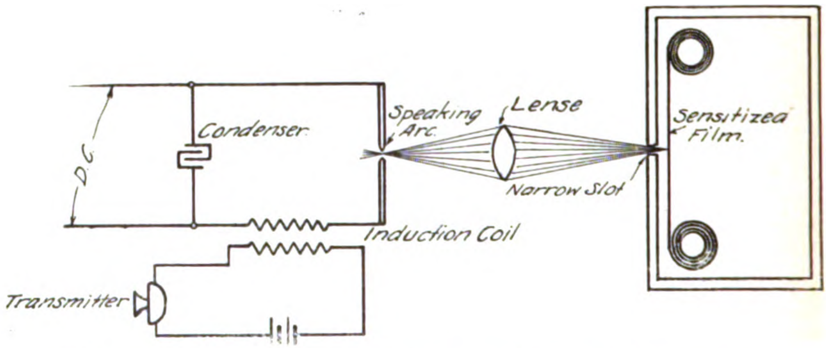

FIG. 1—Ruhmer's selenium cell phonograph recording apparatus.

Photometry. The use of selenium as a measure of light intensity has always been a very attractive experiment. Selenium changes its electrical resistance in proportion to the amount of light falling upon it. If the selenium is in the form of a cell with a current flowing through it, the current will vary according to the resistance, or in proportion to the amount of light falling upon the cell; and any change in the current can easily be measured with our present instruments, thus making a direct-reading photometer. The one great objection to the use of selenium as a photometer, which has not been overcome, is that its resistance gradually changes. What is known as fatigue,

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or soaking, takes place; that is, the resistance of the cell will change rapidly when light first strikes it and keeps slowly changing for some time after. This soaking effect varies greatly with different cells. We have had some cells that acted very slowly, while others seemed to go instantly to a fixed value and stay there as long as the light remained constant. The return of selenium to its dark resistance is very much slower than its change to light resistance.

We have made a photometer with a cell in a bridge circuit with another compensating cell; this appears to give very good results. This apparatus has been on test for four or five months and while our measurements of it are rough, yet the cells apparently have not changed.

Mr. Fitzhugh Townsend has experimented quite extensively with selenium cells and he claims that the same curve for time and light can be secured day after day when readings are taken under certain conditions.

Picture Transmitting Apparatus. Numerous patents have been taken out for picture transmitting apparatus, based on the use of the selenium cell. It is probably only a question of time before a practical machine will be placed on the market. Just how valuable it will become remains to be seen. It may be a means of extending the business man's capacity for doing more work with less effort. It certainly will be valuable to newspapers.

Messrs. S. P. Grace and J. G. Roberts invented, in 1900, a successful instrument for transmitting pictures to a distance. I do not happen to have an exact description of the machine. Most of the machines so far invented consist of a receiving apparatus for varying the resistance of a selenium cell by throwing the light from the focus of a picture by successive steps from different parts of the picture upon the cell. The light from the picture is generally passed through a hole in a screen, which hole travels rapidly backward and forward over the picture, covering every portion of it in regular order. The picture may be produced by an object reflected through a lens or by a strong light reflected through a specially prepared transparent photograph. The receiving end is usually the hard part to design. A sensitized film of some kind is generally used to receive the picture. One of the most common forms, which works comparatively slowly, is to allow a point to travel over a piece of paper soaked with a chemical that bleaches out when a current passes from a pointed electrode dragged over its surface; the successive dots made by the current pulsations form a picture. One patent just issued uses a mechanical punch, worked by an electromagnet, for making the dots.

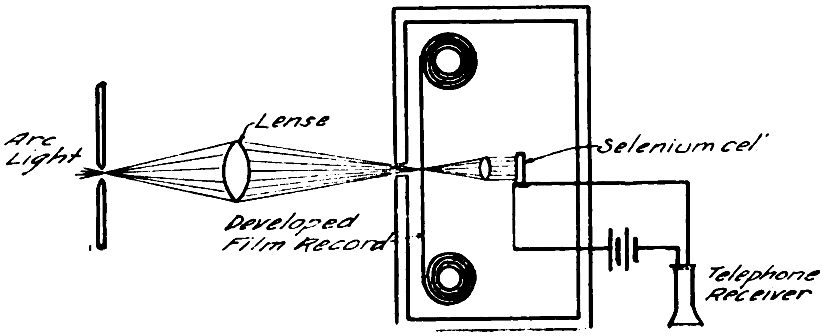

FIG. 2—Ruhmer's selenium cell phonograph reproducing apparatus.

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The current along the line is reinforced by a relay. The sensitive arc flame and the oscillograph have also been tried. The oscillograph promises to give better results as a receiver than any of the others. All the machines of which descriptions have been published print the receiving picture, but none of them can transmit the image of an object from one end to be seen instantly at the other. Rumors of such a machine come from Portland, Oregon, but so far nothing authentic has been published about it.

All picture transmitting apparatus depends upon parts at each end moving in synchronism, so that at the instant when the selenium cell is lighted up from a certain point in the picture and sends out a current it will work the receiving end and print a light spot corresponding to the transmitting end and in exactly the same position at the same instant.

The Western Electrician of Feb. 26, 1907, describes Professor Korn's system of transmitting pictures by electricity. This appears to be a very perfect piece of apparatus. One of the special features of the machine is a method of using an extra selenium cell to compensate the lag in the action of the main cell. Another feature is that he uses a small aluminum shutter in a galvanometer at the receiving end for varying the light.

Selenium Cell Manufacture. Selenium cells are generally made by turning two spiral grooves on a short cylinder of pipe clay, porcelain, or lava, and winding two fine parallel wires in the grooves. The following is from an excellent paper by Professor Townsend, on the selenium cell.

"While in a crystalline form the resistance of selenium is very high and not of much use. It is, however, sensitive to light. By heating for a number of hours either the vitreous form or the crystalline form just described the conductivity of the metal becomes greatly increased, and, if the temperature is reduced very slowly to atmospheric temperature, a high degree of sensitiveness to light is attained. It is in this conducting crystalline form that selenium is employed for signaling purposes. The vitreous form of the element melts at 210 degrees centigrade, but the crystalline forms have a considerably higher melting point.

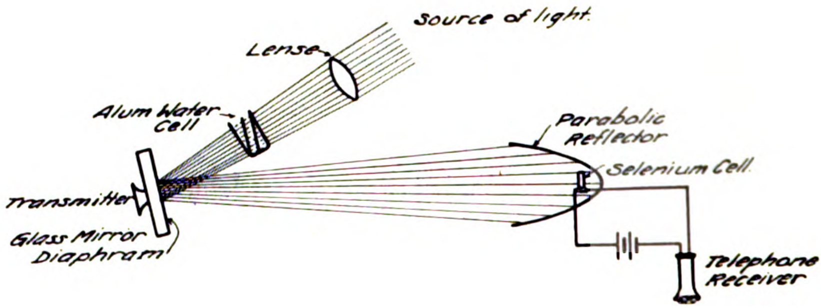

FIG. 3—Bell's telautophone.

Selenium, even when in metallic crystalline form, has an extremely high specific resistance, and it is necessary, therefore, to construct a rheostat made of it in such a way as to offer a great many paths for the current between one terminal and the other. One of the most usual methods is to cut two parallel threads in a refractory tube made of glass or lava, or some such material. A pair of parallel wires are then put on the tube so that

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they run spirally side by side along the threads. These two wires form the opposite electrodes, The tube is then made to spin in a lathe, and at the same time heated somewhat above 210 degrees centigrade. The vitreous selenium is then run along the tube, to which it clings in a thin sheet. This method of construction necessitates the use of a parabolic mirror, because otherwise the light rays would only fall on one-half of the sensitive material. In order to obviate this, resistances can be constructed so as to be plane instead of circular. Alternate plates are connected together and to one of the binding posts.

Another way of accomplishing the same result is to wind two parallel wires close together along a broad piece of refractory material, such as slate.

In order to cut down the ohmic resistance, it is necessary to bring the adjacent wires or steps as near together as possible. This distance should be in any case considerably less than a millimeter. The selenium must be put on so as to form an extremely thin coating, because this light appears to act only on the surface of the metal, it being opaque; therefore, if any appreciable thickness is allowed, a great deal of current will be conducted from one electrode to the other through a part of the material which is not affected by the light, and it is desirable to cause the current to flow along the surface where the resistance is altered by the effect of the light rays.

It is obvious, since the two electrodes are composed of a series of wires or plates extremely close together, that the effect of any moisture deposited on the surface will be very noticeable, and that the surface must be kept dry if the resistance is not to be affected by atmospheric conditions. In the latest developments by Professor Rühmer, of Berlin, the selenium resistance is enclosed in an exhausted glass bulb, this having been found to give the best results.

Higher brass, copper or silver may be used in the construction of a selenium resistance. One of the difficulties in the construction is to make the molten substance stick fast to the electrodes. The selenium appears to combine to some extent with the surface of the metal on which it is desposited when in a molten state, forming an extremely thin layer of selenide; this, however, is brittle when cold and extremely liable to chip off. If the copper or brass is slightly tinned, the adhesion of selenium is facilitated.

After the selenium has been successfully laid over the electrodes in the form of a thin sheet, the resistance thus formed should be baked in an oven at a temperature of approximately 190 degrees centigrade for a period of three hours, after which it should be slowly cooled; this process occupying possibly another three hours.

* * * * * * * *

It will be noted, therefore, that the prolonged baking and slow cooling have the effect of reducing the ohmic resistance, and increasing the sensitiveness. Experiments were carried on to determine the effect of slight impurities in the selenium used, and it was found that one or two per cent. of copper selenide or nickel selenide could be present without affecting to a marked extent the sensitiveness of the resulting resistance."

I have here a number of new style of flat selenium cells designed and manufactured by Mr. H. Otto and myself. I have also connected some of them so as to demonstrate the effect of light. One will ring a buzzer through a relay when I hold a lamp near it. Another will light an incandescent lamp through a relay, and another is connected in series with a battery and voltmeter. The voltmeter needle moves back and forward over the scale as I move the light nearer or farther away from the cell.

Some of these cells measure twenty times higher resistance in the dark than in bright sunlight. The lowest resistance we are able to get is about

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400 ohms light resistance. The cells are very hardy and do not burn out as do wire around cells.

DISCUSSION

R. A. I. SNYDER: Referring to Fig. I, Herr Ruhmer used very small carbons and a small flame for his speaking arc. This was focused on a narrow slot behind which was passed a sensitized film. The primary circuit used to transmit the sound waves to the sensitive arc consisted of a large, heavy transmitter in series with an induction coil and battery. The sound waves striking the transmitter diaphragm are transformed into electrical vibrations which pass through the induction-coil, causing the arc to vibrate and vary the light which passed through the lens and focused on the photographic film passing before the opening in the screen.

After the film was exposed and developed, different light and dark streaks, corresponding to sound waves, showed across it. It was then run through a reproducing apparatus which consisted of an arc lamp focused through a narrow slot on the film. After the light passed through the film the rays were again collected on a selenium cell, which cell was in series with a battery and receiver. By listening into the receiver one could hear very distinct speech. There is practically no weight to the vibrating parts of a phonograph made like this except the transmitter diaphragm.

The arc is very sensitive to any little changes in the current. It responds almost instantly to every vibration of a sound. Sound can also be heard coming from the flame.

S. P. GRACE: This subject is very interesting and opens up possibilities to us telephone men in the way of utilizing our wire plant for transmitting pictures and perhaps direct images. It is very wonderful to think that we can take a photograph of the human voice, so to speak, and that is what Herr Ruhmer did as explained by Mr. Snyder. Then, again, to think that you can take this record and run it before an arc light so that the rays will fall on a piece of selenium and reproduce the original speech, is, I think, a very wonderful thing to do.

A great many inventors have worked on the problem of transmitting pictures over wires. I tried it myself, but did not progress very far. In 1900 Mr. Roberts, now with the Western Electric Company, and myself worked on a machine for transmitting pictures. We did not try to see over the wire. We did succeed in getting a machine which would transmit handwriting and pictures, and we demonstrated it over circuits from 60 to 70 miles long. The pictures were drawn upon tinfoil paper with insulating ink at the transmitting end, and at the receiving end we used a roll of paper which was dipped in a solution. I do not recall the exact nature of that solution. When the current flowed from an iron stylus on to this paper, the paper would turn blue. As the stylus passed over the insulating ink at the transmitting end the current would be reversed and a blue dot would appear at the receiving station. The machine was successful in transmitting handwriting and crude pictures. It worked well enough so that we were able to sell the patent rights. I do not expect that any device of that kind will ever be very successful for commercial work.

With telephone transmission of the voice we are dealing with what might be called longitudinal vibrations, both in the atmosphere and over the wire. When we transmit pictures we have to deal with a multiplicity of transverse vibrations. Professor Korn suggests that pictures may be transmitted by successively exposing various points in the picture to the action of the selenium cell, and the machine at the far end will reproduce the light or dark spots. This works pretty well for picture machines and Professor Korn has used it to some extent. In order to transmit the image direct so that the eye can

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see it, one would have to have all the points exposed in the picture so that the image would be repeated before the eye in one-twelfth of a second. If we can successively expose all the various points in a picture in this space of one-twelfth of a second and then gather the images of the points at the far end, the image will appear continuous. Theories and schemes for doing this have been worked out and I believe its accomplishment is only a question of mechanical and electrical refinement. I confidently look forward to the direct transmission of images by means of electricity o•er wires, possibly within the next five or ten years.

H. W. FISHER: I noticed in one of the telephone papers that light from some source, passed through a picture and then upon the selenium cell, affected it. This was transmitted through a wire and passed through a galvanometer which controlled and varied the light so that more or less of it passed through and formed the picture. This light fell on a sensitized screen. The beam of light was carried straight across and traced with different intensity on the sensitive film, depending on the movement of the galvanometer. The pictures that were transmitted were very good indeed. I do not know whether it is in commercial shape or not.

F. W. HARRIS: Is the selenium cell affected mostly by the visible or invisible light of the spectrum? and how well will a selenium cell photometer compare lights of different colors?

R. A. L. SNYDER: I believe that the selenium cell, taking the summation of the light from the different colors of the spectrum, is affected more by the visible rays of the spectrum than by the rays outside the spectrum. Of course in photometry there always will be more or less of a controversy as to which color gives the more intense and useful light. With any form of photometer it is pretty hard to compare different colored lights.

Twenty-fourth Annual Convention at Niagara Falls, June 25-28, 1907

The Twenty-fourth Annual Convention of the American Institute of Electrical Engineers was held at the Cataract Hotel, Niagara Falls, N. Y., beginning Tuesday morning, June 25, and ending Friday afternoon, June 28, 1907. About 475 members and guests attended the various professional and social events. The professional papers covered a large variety of subjects, and the discussions were animated and interesting. A large number of those attending availed themselves of the courtesies extended by the local power and manufacturing companies, obtained through the efforts of an active and thoughtful local committee. Not the least enjoyable of the social events was a delightful reception and dance given under the auspices of the local committee in the ball-room of the Cataract Hotel on Thursday evening, June 27. The local committee consisted of Philip P. Barton, chairman; E. G. Acheson, H. B. Alverson, F. B. H. Paine, and W. N. Ryerson.

MONDAY MORNING, JULY 25, 1907.

The convention was called to order by President Samuel Sheldon at 10:15 a.m. He introduced the Honorable A. C. Douglass, mayor of Niagara Falls. Mayor Douglass welcomed the Institute in the following words.

MAYOR DOUGLASS: I welcome you to our city. Fifteen years ago I came to Niagara as a contractor and undertook the building of the first canal and wheel pit, planned to harness the energies of the great Niagara. In those days we knew very little, compared with to-day, about electricity. I have watched, with great interest, experiments at the power house, made by eminent engineers of this and other countries, but have made very little study of the theory of electricity.

My connection with the work has always been that of a contractor building the tunnels and wheel pits and pre-

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paring them for the machinery. My last contract was the building of the tunnel and wheel pit for the Electric Development Company of Ontario. This tunnel is one that discharges its water beneath the Horseshoe Falls. At the time this tunnel was proposed there was a great deal of speculation as to what we would encounter when making our opening or outlet beneath the falls.

To accomplish this work we sank a shaft on the Canadian shore 155 feet deep and drove a small tunnel a distance of 750 feet under the crest of the falls to a point on the line of the main tunnel. When this tunnel had reached a distance of 500 feet from the shaft, we drove a cross-cut to make an opening to the river below the falls. In doing this we encountered a large open fissure vein that allowed the water to enter and flood the tunnel. It was then necessary to find out the conditions outside under the sheet of water.

I organized an exploring party, consisting of myself and two of my best foremen, and after several attempts were made from the Canadian shore we reached a point beneath the falls where the opening was to be made and began operation from the outside.

Knowing that the action of dynamite, when exploded, is downward, we placed a box of fifty pounds on the top of the rock and exploded this by means of a battery. This pulverized the rock so that the water would carry it away. After using some 10,000 pounds of dynamite in this way I cleared an opening to the branch tunnel. After this was accomplished the work became quite easy, for in place of hoisting the balance of the material excavated from the tunnel to the surface, I used this opening as a dump, and all material from the excavation was put out into the lower river with very little trouble.

It is always customary when a man is elected mayor of a city to try and give the people something new, and on this line I have been trying to interest the people of Niagara Falls in the illumination of the falls. With your kind indulgence for a few moments I will give you a general idea of a plan submitted by the General Electric Company, through their illuminating expert, Mr. W. D'A. Ryan.

The proposed illumination of the falls by Mr. W. D'A. Ryan consists of two batteries, one of five 60-inch projectors, mounted at the highest available point on the Canadian side, so placed as to catch the crest of the falls and plunge the light into the broken waters as it rushes down between the bridge and the brink on the American side.

They will be so placed that they can be used to advantage to sweep the rapids on the Canadian falls. The color attachments will be used so as to change the water various shades, including crimson, carmine, orange, yellow, green, violet, and purple of the purest shades obtainable. These various tints will be combined in different ways so as to produce innumerable pleasing tints and shades in various combinations.

The second battery will consist of twenty-five 36-inch projectors mounted in the form of a crescent at the base of the gorge on the Canadian side. This will also be provided with color attachments, and the projectors will be so placed that they can be concentrated on either the American or the Canadian falls, or subdivided so as to cover the American and Canadian falls.

Along the edge of the water opposite the battery in the gorge, the scintillator head will be installed and also the mortars for discharging the smoke bombs and mines; and it is the intention to select, say two or possibly three nights a week for special illumination, and on all other nights illumination without special features.

The illumination without special features consists merely of throwing white light on the falls without attempting any spectacular effects. On special feature nights the program will be as follows:

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1. There will be, say, three aerial maroons exploded with heavy detonations at an elevation of about 500 feet, throwing out large banks of white smoke. As the smoke floats away it will be picked up by the gorge battery and tinted similar to the clouds at sunset.

2. Reflected aurora-borealis by the gorge battery, supplemented by the cliff battery; as these rays reach into the sky, an ever changing color and tints will be reflected in the water and will be visible from all points around the falls or gorge, and in suitable atmospheric conditions the beams of the sky would be visible in Buffalo and Rochester to such a degree as to excite comment.

3. Play of color over the water and cliffs and under the suspension bridge.

4. Black powder, smoke mine discharged from mortar at the base of gorge in front of the gorge battery. As the smoke rises from the gorge it will pass through a variety of beautiful tints and colors.

5. Concentration of colors on the scintillator head and colors from the various steam figures as they are introduced will be strongly reflected in the waters of the gorge, similar to a sunset.

6. Concentration of white light from the gorge battery on to the American falls, and the concentration of the cliff battery on the head waters and crest of the American falls.

7. Concentration of gorge battery on the Canadian falls. White light projection of cliff battery on head waters and crest of the Canadian falls.

8. Concentration of both batteries on to the cave of the winds falls. The introduction of colors in complimentary tints.

9. Simultaneous bursts of white light from subdivided batteries on the entire American and Canadian falls.

10. Gradual introduction of various colors in complimentary tints into the water, foam, and mist.

11. Simultaneous discharge of three confetti bombs from Goat Island, timed to explode at the height of about 1000 feet.

Combined batteries in color concentrated on smoke and floating particles.

This whole display will last at least one hour and can be drawn out longer if desirable. The program to be changed on different nights, with special features in the winter time when the effect will be enhanced by the snow and ice upon the trees and other objects in the surrounding parks. Wonderful effects can also be obtained during a snow storm, which would be a special attraction in itself, The entire proposition is to illuminate Niagara in a distinctive and dignified manner and on a scale in keeping with the surroundings.

This, I have every reason to believe, will be accomplished this year, and in place of the people coming here and viewing the falls in the day time, it will be an attraction which will keep them here, not only one day, but for several days, and make Niagara Falls one of the greatest convention cities in this country.

In closing I wish to extend to you the freedom of our city, and assure you that I stand ready to do anything in my power to make this convention the most sucecssful one ever held by the American Institute.

Following out the spirit of the amended Constitution, President Sheldon then introduced the President-elect, Mr. Henry G. Stott, who said:

President-elect Stott: I wish to express my deep appreciation of the confidence which you have placed in me in entrusting the office of president of the Institute to me for the ensuing year, an honor which I appreciate very highly. It is becoming increasingly hard, I think, for any man to fill that position, because each president seems to be just a little bit better than the previous one, and sets a standard just a little higher than his predecessor. However, gentlemen, my great aim will be to endeavor to carry out the work of the Institute along the same

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lines upon which it has been so ably carried out by Dr. Sheldon and his predecessors.

The position of chairman of the Committee on Papers, which I have occupied, has perhaps enabled me to see one or two points in which we may improve the work of the Institute slightly. For example, I propose to enlarge the Committee on Papers, by forming sub-committees on various subjects. We are limited to five members on the Committee on Papers, but I propose to have each member of the committee a chairman of a sub-committee. One of the sub-committees, for which there is a great necessity, is a committee on railways. The electrification of railways is a subject of such vast importance at the present time that it will take the entire time of one committee to cover it. Then we will probably have one of the members of the main committee, chairman of a sub-committee on lighting, and another chairman of a sub-committee on general engineering, and by utilizing the members of the main committee to be chairmen of sub-committees we can in this way enlarge our original committee on papers very materially.

I wish to ask your best efforts in backing up the new chairman of the Papers Committee. Dr. Sheldon has very kindly appointed Mr. Percy H. Thomas, at my request, as chairman of the Papers Committee. This will enable him to get to work at once on the papers for the coming year, and Mr. Thomas is so well known to you all that I feel sure it only requires the mention of his name to make sure that you will all give him your best assistance in preparing a program of papers for the coming year which will be at least commensurate with that which we have had in past years.

I thank you again, gentlemen, for the great honor you have conferred upon me and I trust that I will be able to keep the office of president up to the standard at which it is placed at the present time.

The following papers were then presented and discussed.

1. "The Properties of Electrons". President's Address, by Samuel Sheldon (There was no discussion on this address.)

2. "The Heating of Copper Wires by Electrical Current", by A. E. Kennelly and E. R. Shepard. (In the absence of the authors this paper was read by title).

3. "Power-Factor, Alternating-Current Inductive Capacity, Chemical and other Tests of Rubber-covered Wires of Different Manufacturers", by Henry W. Fisher. This paper was discussed by Messrs. C. P. Steinmetz, E. W. Stevenson, Henry G. Stott, and Henry W. Fisher.

4. "Interaction of Synchronous Machines", by Morgan Brooks. This paper was discussed by Messrs. E. J. Berg, C. P. Steinmetz, and Morgan Brooks.

The first session of the convention ended here, recess being taken for luncheon, followed by a trip on the gorge trolley road in the afternoon.

Tuesday Evening, June 25, 1907.

President Sheldon called the meeting to order at 8:15 p.m., and introduced Mr. T. Commerford Martin, chairman of the Institute Building Fund Committee. Mr. Martin then made the following remarks:

T. Commerford Martin. It is an old story that I have to present to you—the obligations and financial pledges that the Institute assumed when it accepted from Mr. Andrew Carnegie its share of his gift of a million and a half dollars.

The building stands on land which cost \$540,000 and electrical engineers had, in order to participate in the benefits of the building, to assume one-third of that indebtedness, which amounts to \$180,000. For the last two years I have had the honor and privilege of serving the Institute as chairman of its Building Fund Committee, and without any intention or desire to exaggerate the work which has been accomplished

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in that period I think I may say it has been a gratification and somewhat of a surprise to all of us to know that in that period, counting in the work which was done previously, the Institute has secured pledges and promises of nearly $165,000. President Sheldon at the time of the annual meeting of the Institute was able to present a report stating that subscriptions had reached $163,734.00 and that the cash receipts at that time, deposited in bank, reached the sum of $124,829.00. Up to the present time the money has been secured with a fair amount of effort and has come in with decent alacrity, but we have pulled in all the slack and it seems to me that there will be perhaps more difficulty in securing the remaining small amount of $21,000 than we had in raising the $164,000.

Up to the present time nearly 1,000 members of the Institute have contributed. I am rather proud of that record on behalf of the Institute, as I believe it represents a larger percentage of members subscribing to a fund to the common good than has been secured by any other engineering body in this country, or probably throughout the world. That is something in itself to be proud of; but, gentlemen, it leaves 3,000 members and more who have not lifted a finger to enable the Institute to carry on this work and free itself of the financial obligations which to-day lie heavily upon it as a bar to the full accomplishment of its utilities and public service.

I should like to give you an interesting little analysis of the subscriptions we have received, showing that the largest number is that of 376 members who have each pledged themselves for the sum of $25.00. As that has been spread over a period of five years you can see that each member has virtually agreed to give us $5.00 a year. I do not think that even with the smallest and most modest salary that can be regarded as very much of a tax upon a man's income. I think that a man gives to himself and to his fellows a pledge of his ambitions and of his future when he shows how much he is interested in the broader work of the Institute as a whole.

The following papers were then presented.

1. " Protective Apparatus Engineering", by E. E. F. Creighton.

2. " Practical Testing of Commercial Lightning-Arresters", by Percy H. Thomas.

3. " Proposed Lightning-Arrester Test", by N. J. Neall.

These three papers were then discussed by Messrs. C. P. Steinmetz, E. E. F. Creighton, Percy H. Thomas, and W. S. Lee.

4. " Inductive Disturbances in Telephone Lines", by Louis Cohen. (In absence of the author this paper was read by title.)

Wednesday Morning, June 26, 1907.

Calling the meeting to order at 10 a.m., President Sheldon said: " The official delegates with the officers of the Institute will dine together on Thursday evening, 6:30 p.m., in the small dining room of the International Hotel. After dinner there will be an informal discussion upon ' Section and Branch Affairs and their Relation to the Institute.' " The following papers were then presented.

1. " Choke-Coils Versus Extra Insulation on the End Windings of Transformers", by S. M. Kintner.

2. " Protection of the Internal Insulation of a Static Transformer Against High-Frequency Strains", by Walter S. Moody.

3. " Notes on Transformer Testing", by H. W. Tobey.

These papers were then discussed by Messrs. A. H. Pikler, K. C. Randall, D. B. Rushmore, P. M. Lincoln, E. J. Berg, J. W. Fraser, W. N. Smith, C. W. Stone, E. E. F. Creighton, William McClellan, Morgan Brooks, W. S. Lee, R. P. Jackson, C. P. Steinmetz, Ralph D. Mershon, W. L. R. Emmet, O. S.

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Lyford, Jr., H. W. Buck, S. M. Kintner, Walter S. Moody, and H. W. Tobey.

4. " Transmission Line Towers and Economical Spans ", by D. R. Scholes.

5. " Lightning-Rods and Grounded Cables as a Means of Protecting Transmission Lines Against Lightning ", by Norman Rowe (In the absence of the author this paper was read by Mr. Ralph D. Mershon.)

These two papers were then discussed by Messrs. William Hoopes, Percy H. Thomas, W. S. Lee, F. B. H. Paine, C. W. Ricker, G. T.Fielding, N. J. Neall, J. W. Fraser, Ralph D. Mershon, and D. R. Scholes.

Wednesday Afternoon, June 26, 1907.

While most of the members and guests were attending a delightful afternoon tea at the Natural Food Company's conservatory, 40 members of the Institute attended a " rump " meeting in the assembly room of the Cataract Hotel to discuss high-tension transmission matters. In the absence of President Sheldon, Mr. Ralph D. Mershon, chairman of the High-tension Transmission Committee, presided.

The following papers were presented.

1. " A New Type of Insulator for High-Tension Transmission Lines ", by E. M. Hewlett.

2. " Some New Methods in High-Tension Line Construction ", by H. W. Buck.

These papers were then discussed by Messrs. J. B. Whitehead, Ralph D. Mershon, Ralph W. Pope, N J. Neall, J. W. Fraser, L. G. Robinson, Percy H. Thomas, F. B. H. Paine, E. N. Hewlett, and C. P. Steinmetz.

3. " The Transmission Plant of the Niagara, Lockport and Ontario Power Company ", by Ralph D. Mershon.

This paper was discussed by Messrs. J. W. Fraser, Ralph D. Mershon, N. J. Neall, E. J. Berg, F. B. H. Paine, W. S. Lee, and L. G. Robinson.

4. " Location of Broken Insulators and Other Transmission Line Troubles", by L. C. Nicholson.

This paper was discussed by Messrs. J. W. Fraser, Ralph D. Mershon, H. W. Buck, L. G. Robinson, F. B. H. Paine, E. M. Hewlett, Percy H. Thomas, and C. P. Steinmetz.

By way of discussion, Dr. Steinmetz read a paper entitled: " Notes on Resistance of Gas-pipe Grounds," by Mr. J. L. R. Hayden. The members present treated Mr. Hayden's comments as an original paper and discussed it somewhat at length, the following members taking part in the discussion: Messrs. Ralph D. Mershon, C. P. Steinmetz, Percy H. Thomas, N. J. Neall, F. B. H. Paine, and E. M. Hewlett.

Wednesday Evening, June 26, 1907.

President Sheldon called the meeting to order at 8:20 p.m. Before taking up the technical papers and discussions, President Sheldon read the following telegram from Past-president Arnold:

" I had hoped and fully expected to be with you to-day, but now regret to find it is impossible to go to the convention. I am with you in spirit, and have no doubt the convention will be interesting and profitable.

BION J. ARNOLD."

This being a formal session of the Institute, the work of the informal session during the afternoon was duplicated and the following papers presented.

1. " The Transmission Plant of the Niagara, Lockport and Ontario Power Company ", by Ralph D. Mershon. (In the absence of Mr. Mershon the paper was presented in abstract by Mr. P. M. Lincoln.)

2. " Location of Broken Insulators and Other Transmission Line Troubles", by L. C. Nicholson.

3. " A New Type of Insulator for High-Tension Transmission Lines", by E. M. Hewlett.

4. " Some New Methods in High-Tension Line Construction ", by H. W. Buck.

5. " Switchboard Practice for Voltages of 60,000 and Upward ", by Stephen Q. Hayes.

These papers were then discussed by

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Messrs. P. M. Lincoln, F. B. H. Paine, J. B. Taylor, D. B. Rushmore, E. B. Merriam, William McClellan, W. N. Smith, S. L. Nicholson, E. M. Hewlett, H. W. Buck, and Stephen Q. Hayes.

Thursday Morning, June 27, 1907.

President Sheldon called the meeting to order at 9:45 a.m. The following papers were presented:

1. "Deflocculated Graphite", by E. G. Acheson. Before reading this paper, Mr. Acheson made a number of experiments illustrating the points brought out in the paper and showing the chemical and physical properties of this form of graphite. The reading of the paper was followed by an interesting discussion by Messrs. D. B. Rushmore, W. L. R. Emmet, Carroll Thomas, and E. G. Acheson.

2. "Single-Phase Versus Three-phase Generation for Single-Phase Railways", by A. H. Armstrong.

This paper was discussed by Messrs. P. M. Lincoln, Henry G. Stott, Vladimir Karapetoff, J. B. Taylor, William McClellan, C. P. Steinmetz, and A. H. Armstrong.

3. "The Choice of Frequency for Single-Phase Alternating-Current Railway Motors", by A. H. Armstrong.

4. "Twenty-five versus Fifteen Cycles for Heavy Railway Service," by N. W. Storer.

These two papers were discussed by Messrs. H. G. Reist, C. W. Stone, E. J. Berg, L. B. Stillwell, W. N. Smith, William McClellan, C. P. Steinmetz, Charles F. Scott, Peter Junkersfeld, Gano Dunn, Henry G. Stott, A. H. Armstrong, and N. W. Storer.

Immediately after the close of the morning session a photograph of the members and guests in attendance at the convention was taken on the greensward bordering the rapids west of the Cataract Hotel.

Thursday Afternoon, June 27, 1907

President Sheldon called the meeting to order at 2:30 p.m. The following papers were presented:

1. "Commutating-Pole Direct-Current Railway Motors", by E. H. Anderson.

This paper was discussed by Messrs. Gano Dunn, J. C. Lincoln, E. H. Anderson, and W. N. Smith.

2. Report of the Committee on "A Code of Ethics".

An interesting discussion on this report was participated in by Messrs Schuyler Skaats Wheeler, William McClellan, Henry G. Stott, Gano Dunn, H. W. Buck, Ralph W. Pope, C. P. Steinmetz, C. W. Ricker, C. W. Stone, Carroll Thomas, E. H. Schwarz, C. F. Scott, W. L. R. Emmet, N. W. Storer, and J. M. Knox.

3. "The Attitude of the Technical School Toward the Profession of Electrical Engineering," by H. H. Norris.

4. "The Concentric Method of Teaching Electrical Engineering," by Vladimir Karapetoff.

These two papers were discussed by C. E. Magnusson, F. B. Crocker, Gano Dunn, Samuel Sheldon, William Esty, C. S. Howlett, G. W. Patterson, Lester W. Gill, L. B. Nordstrum, Vladimir Karapetoff, C. F. Scott, and H. H. Norris.

5. Standardization Rules. On motion of Gano Dunn, duly seconded, the convention endorsed and formally accepted the revised Standardization Rules.

Thursday Evening, June 27, 1907.

As noted in the opening paragraph of this report, a delightful reception and dance under the auspices of the local committee was given in the ballroom of the Cataract Hotel. The evening was cool, and the floor and music so seductive that this most enjoyable affair lasted until three o'clock Friday morning.

Section and University Branch Dinner and Discussion.

Much credit is due Mr. Paul Spencer, chairman of the Committee on Local Organizations, for arranging for the informal dinner given by the officers of

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of the Institute to the Section and Branch delegates to the convention. on Thursday evening. The dinner was held in the private dining room of the International Hotel, and covers were laid for fifty guests. After dinner there was an interesting informal discussion of Section and Branch matters by Messrs. Sheldon, Spencer, Scott, Steinmetz, Esty, Rushmore, Magnusson, Berresford, Norris, Stott, and others.

Friday Morning, June 28, 1907.

President Sheldon called the meeting to order at 9:45 a.m. On motion of Henry G. Stott, the report of the Committee on a Code of Ethics was, in accordance with the revised Constitution, referred to the Board of Directors for further action. This motion was seconded by L. B. Stillwell and adopted by the Convention. The following papers were then presented.

1. "Regeneration of Power with Single-phase Electric Railway Motors", by William Cooper.

This paper was discussed by W. I. Slichter, L. B. Stillwell, J. C. Lincoln, and William Cooper.

2. "Fractional Pitch Windings for Induction Motors", by Comfort A Adams, W. K. Cabot, and G. Æ. Irving, Jr.

3. "Zigzag Leakage of Induction Motors", by R. E. Hellmund. (In the absence of the author the paper was read by A. S. McAllister.)

These two papers were then discussed by Messrs. J. C. Lincoln, B. T. McCormmick, C. P. Steinmetz, Comfort A. Adams, and A. S. McAllister.

4. "The Vector Diagram of the Compensated Single-Phase Alternating-Current Motor", by W. I. Slichter. This paper was discussed by Mr. Vladimir Karapetoff.

Friday Afternoon, June 28, 1907,

President Sheldon called the meeting to order at 2:30 p.m. The following papers were presented.

1. "Track-Circuit Signalling on Electrified Roads", by L. F. Howard. This paper was discussed by Messrs. C. F Scott, Henry G. Stott, C. A. Perkins, and L. F. Howard.

2. "Some Power Transmission Economics", by Frank G. Baum. In the absence of the author the paper was read by title, and then discussed by Messrs. C. P. Stenimetz and F. B. H. Paine.

3. "Single-Phase High-Tension Power Transmission", by E. J. Young. In the absence of the author the paper was read by title, and then discussed by Messrs. C. P. Steinmetz and E. H. Schwarz. This concluded the technical papers and discussions.

As a mark of appreciation of the efforts made by the authors, those taking part in the discussions, the many courtesies extended by the local committee, and the local industries, the Institute passed the following resolutions:

HENRY G. STOTT. I move that a hearty vote of thanks be accorded to the various writers of the papers presented at this meeting; to the local reception committee for the very excellent arrangements which have been made for this convention and for the excellent manner in which they have been carried out; and also to the following companies: Bell Telephone Company, Cataract Power and Conduit Company, Niagara Falls Power Company, Niagara Falls Hydraulic Power and Manufacturing Company, Westinghouse Electric and Manufacturing Company, Ontario Power Company, Niagara, Lockport and Ontario Power Company, General Electric Company, Electric Development Company of Ontario, and the Canadian Niagara Power Company.

The President put the above motion to a vote, and it was unanimously carried.

HENRY G. STOTT. I also move a hearty vote of thanks to our local committee of the Institute, especially the following, Mr. Barton, Mr. and Mrs, Paine, and Mr. and Mrs. Ryerson. I think all of us, especially the ladies, have appreciated the many efforts that

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have been made for our entertainment and the courtesies shown us, by and in behalf of the committee, particularly in the privileges which have been extended to us to visit the various power companies which have opened up their plants and shown us so many things of interest.

C. F. SCOTT. In regard to the local committee, it seems especially proper that we should express our appreciation for what the local committee has done for us here, becaues in a way Niagara Falls differs from other places. In other places it may be a privilege to them to have the Institute hold a meeting in their cities, as they do not have distinguished bodies convene in their cities oftener than once in ten years perhaps. In place of this kind, where celebrated bodies come every week or two, it is somewhat of a task on the local people to keep up a welcome, but they have done it so heartily and cordially this week that they deserve our special thanks.

The President put the motion of Mr. Stott, which was unanimously carried.

The papers presented at this convention cover approximately 600 pages of printed matter; the verbal discussion as reported by the official stenographer covers 319 pages of typewritten matter, or approximately 250 additional pages of printed matter. In brief, the entire Convention proceedings will fill a volume equal in size to the average bound TRANSACTIONS.

Bound Volumes

Having received a number of inquiries verbally and by mail about the distribution of the TRANSACTIONS for last year, it seems worth while to explain somewhat in detail the various processes occuring between the receipt of a manuscript and its final appearance in the annual bound volume. As far as Institute office routine is concerned, there are no less than twenty-two distinct operations necessary before a manuscript illustrated with cuts appears in the PROCEEDINGS. All of these operations require time, and most of them require ability, tact, and gumption. When a paper is printed in the PROCEEDINGS it bears in the upper left-hand corner of the first page the announcement: "Subject to final Revision for the TRANSACTIONS." After the PROCEEDINGS is distributed, every author receives a separate copy of his paper with the request that he approve it for final printing in the TRANSACTIONS. Having received the author's approved copy, the copy is then re-read for possible typographical errors; the necessary corrections are made, and the pages sent to the foundry to be electrotyped. Virtually the same routine prevails in regard to the discussions on papers.

As the last meeting for the year occurs on the fourth Friday of December, the necessary routine compels the printing of the discussion at the December meeting in the second issue of the PROCEEDINGS following that meeting. Obviously, this condition holds true throughout the year. The December discussion, then, is usually printed in the February PROCEEDINGS. Necessary routine again steps in and prevents the electrotyping of this discussion until after the version in the PROCEEDINGS is sanctioned by the authors. This brings us up to April first. After the last discussion is electrotyped, the printer submits page-proofs of all the papers and discussions printed during the year, usually about 1,000 pages. As these papers and discussions are in a chaotic state as far as chronological order is concerned, there begins the arduous task of re-arranging the pages so as to have the papers follow in the order of the date of presentation, and the discussion or discussions—frequently there are Section and Branch discussions of great value—placed immediately after the paper to which they refer. This task must be done deliberately and systematically. It is now May first.

After all the pages are re-numbered and the "running heads" on the discussions

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correctly inserted—in the process of re-arranging a discussion to follow a paper it is often necessary to transpose and recast these heads—the plates are returned to the foundry to have the old folios removed and new folios inserted. To change the folios on 1,000 pages of Institute matter takes about two weeks' time. It is now June first. Page proofs with the new folios are then pulled and checked against the editor's copy. The printing of the TRANSACTIONS is commenced, and the printer ordered to put all his available presses to work. Obviously again, this is a process that requires great care and a large time-element; to print 4,750 copies of a book of 1,000 pages—the edition of Volume XXV, for 1906—takes about one month. It is now July first.

Then the index and table of contents are compiled, another arduous and time-consuming process. While this is going on, the binder is at work on the papers and discussions. To bind and deliver the entire edition takes about another month. It is now August first. All these volumes have to be wrapped, addressed, checked, and shipped—all with the ordinary office force reduced by the vacation season. This takes another six weeks. It is now September 15.

As implied in the editorial comment in the June PROCEEDINGS, the work of getting out the TRANSACTIONS is done by a limited editorial staff during the brief intervals between the peak-loads caused by the regular monthly and the extra Institute meetings held from September to the annual convention in June. The greatest stress usually comes during the so-called vacation season. Fortunately, by dint of some ingenuity, several of these various processes can be made to overlap; two processes, such as electrotyping one part of the TRANSACTIONS, and printing another part can be carried on at the same time, thus saving from four to six weeks' time, making it possible to distribute the volume about August 15 instead of September 15. The distribution of Volume XXV, for 1906, will begin about August 15 of this year.

Associates Elected

At a regular meeting of the Board of Directors held in the Engineers' Building, 33 West Thirty-ninth street, New York, Friday, July 26, 1907, at 3:30 p. m., the following 229 Associates were elected:

AANONSEN, HANS EDWARD, Designer, Niagara, Lockport and Ontario Power Co., 517 Fidelity Bldg.; res., 248 Ashland Ave., Buffalo, N. Y.

ABBOTT, FRED HATHAWAY, Electrical Engineer, Houghton County Electric Light Co., Houghton, Mich.

ADAMS, LELAND ROSE, Local Manager, Cumberland Telephone and Telegraph Co.; res., 105 Orange St., Monroe, La.

ALBRIGHT, LANGDEN, Assistant, Engineering Department, Ontario Power Co.; res., 730 W. Ferry St., Buffalo, N. Y.

ALLISON, ARTHUR, Testing Electrician, Noyes Bros., Dunedin, N. Z.

ALTON, RALPH HENRY, Construction Superintendent, General Electric Co., Schenectady, N. Y.

ANDREW, JOHN OSCAR, Chief Operator, Southern Power Co., Great Falls, S. C.

BAER, FREDERICK LUDWIG, Installer in Chief to Home Telephone Co., Automatic Electric Co., Oakland, Cal.

BALDWIN, EDWARD ARTHUR, Electrical Engineer, General Electric Co., Schenectady, N. Y.

BALLWEG, JOHN HARLAN, Electrician, Baker Light & Power Co., Baker City, Oregon.

BARNHOLDT, HAROLD L., Assistant Engineer, Stanley G. I. Electric Mfg. Co.; res., 219 1st St., Pittsfield, Mass.

BAUR, FRED J., Rotary Station Attendant, Toledo and Indiana Railway Co., Holland, O.

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BEAUREGARD, ARMAND TOUTANT, Laboratory Engineer, Public Service Corporation of N. J., 102 River St., Newark, N. J.

BEILSTERN, LOUIS EDWARD, General Manager, Toledo Railways and Light Co., Toledo, O.

BENJAMIN, GEORGE R., Electrical Department, Western Union Telegraph Co., 195 Broadway, New York City.

BERRY, ALFRED HERBERT, Electrical Engineer, Moore Spinning Co.; res., 419 Lincoln St., Lowell, Mass.

BINNEY, HAROLD, Partner, Binney Breckenstein and Ogden, 2 Rector St.; res., 10 Lexington Ave., New York City.

BOLEN, WALTER ISRAEL, Foreman of Construction, General Electric Co., Mexico City, Mexico.

BOSTATER, HERBERT LEE, Engineer, Western Electric Co., 259 So. Clinton St.; res., 2419 W. Huron St., Chicago, Ill.

BOVELL, CARYL HARRISON, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.

BOWEN, ABRAM CLERKE, District Inspector, New York and New Jersey Telephone Co., 25 Market St., Morristown, N. J.

BRENTON, CHARLES ELMER, Assistant to Auditor, Union Electric Light and Power Co.; res., 1244 Aubert Ave., St. Louis, Mo.

BRETT, GEORGE EDWIN, Superintendent, Electrical Department, Wilkes-Barre Gas and Electric Co., 27 N. Main St., Wilkes-Barre, Pa.

BROWN, EDWARD BYAM, Student, General Electric Co.; res., 11 Baker St., Lynn, Mass.

BROWN, HERBERT C., Engineering Department, Rocky Mountain Bell Telephone Co., Salt Lake City, Utah.

BRU, EDMUND H., Electrical Engineer, Cia de Real del Monte y Pachuca, Pachuca, Hgo, Mexico.

BUCK, ALFRED H., Wire Chief, New York Telephone Co., 114 W. 89th St., New York City.

BUCKWELL, THOMAS DOUGLAS, Contract Agent, Toledo Railways and Light Co.; res., 2508 Maplewood Ave., Toledo, O.

BURKHART, HARRY E., Electrical Contractor, 2567 Broadway, Toledo, O.

BURNHAM, LOCKE HENRY, Designing Engineer, General Electric Co.; res., 15 Forest Pl., Pittsfield, Mass.

CALDWELL, HARRY LIND, Inspector, North Shore Electric Co.; res., 1661 Thorn St., Chicago Heights, Ill.

CHURCH, MAYNARD D., Kerr Turbine Co., 151 Madison St., Wellsville, N. Y.

CLARKE, EDWIN HAVENS, Engineer, New York and Pennsylvania Tel. and Tel. Co., Syracuse, N. Y.

CLARKE, FRANK J., Engineer's Inspector, Southern Bell Telephone and Telegraph Co., Atlanta, Ga.

CLAYTON, H. F. R., Superintendent, Philadelphia Electric Construction Co., 914 Filbert St.; res., 63 N. Millick St., Philadelphia, Pa.

CLEAVELAND, HORACE BROOKS, Tester, General Electric Co.; res., 26 Division St., Schenectady, N. Y.

CLEVENGER, FRED SIEGLE, Supervising Foreman of Cable Splicers, New York and New Jersey Telephone Co., 547 Clinton Ave., Brooklyn, N. Y.

COLBY, CHARLES EBEN, Assistant Foreman, Motor Testing, Eddy Electric Corporation, Windsor, Conn.

COLE, JAMES E., Chief Electrician, Wire Department, City of Boston; res., 64 Perham St., Boston, Mass.

CONGDON, FRANK EDWIN, District Inspector, New York Telephone Co., 18 Cortlandt St., New York City; res., 3 Vincent Pl., Montclair, N. J.

COX, A. B., Tester, General Electric Co.; res., 48 Mall St., Lynn, Mass.

CREESE, MYRON, Instructor Electrical Engineering, Pennsylvania State College, State College, Pa.

CURRIE, JAMES ELMER, in charge of Inside Construction, Dayton Lighting Co., Dayton, O.

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DARRAH, HARRY LE ROY, Telephone Engineer, Western Electric Co., 463 West St., New York City.

DAVISON, EDWARD FLETCHER, Electrical Engineer, Rochester Electric Motor Co., 284 State St., Rochester, N. Y.

DEAKIN, GERALD, Assistant Engineer, Pacific Telephone and Telegraph Co.; res., 3940 Washington St., San Francisco, Cal.

DECHANT, HENRY G., Switchboard Sales Department, Western Electric Co., 463 West St., New York City.

DEEDS, HARRY W., Assistant Engineer, Pacific Telephone and Telegraph Co., San Francisco, Cal.

DIEMER-HANSEN, JENS LUDVIG, Chief Electric Engineer, Siam Electricity Co., Bankok, Siam.

DODDS, CHARLES THOMAS, Manager, Dean Electric Co., 160 So. Mentor Ave., Pasadena, Cal.

DOW, ROY GAY, Inspection Work, Western Electric Co., 463 West St.; res., 147 Edgecombe Ave., New York City.

DU BOIS, ARTHUR L., Wire Chief, New York Telephone Co., 614 E. 150th St., New York City; res., Grantwood, N. J.

DURBIN, VERNON, Telephone Engineer, Holtzer Cabot Electric Co., Brookline, Mass.

DURFEE, CHARLES GUSTAVUS, Foreman Electric Meter Department, Rochester Railways and Light Co., Rochester, N. Y.

EDWARDS, IRVING W., Engineering Assistant New York and New Jersey Telephone Co., 81 Willoughby St., Brooklyn, N. Y.

ELLIOTT, LOUIS, Construction Engineer, Central Colorado Power Co., Colorado Springs, Colo.

ENDERISS, HORACE D., Assistant Manager, Jandus Electric Co., Philadelphia, Pa.

FASHBAUGH, WILLIAM N., Electrcian, Western Union Telegraph Co., 195 Broadway; res., 545 W. 148th St., New York City.

FELKER, CARL HENRY, First Assistant Contract Agent, Toledo Railways and Light Co., 339 Superior St. Toledo, O

FELT, JOHN E., Student; res., 3123 Detroit Ave., Toledo, O.

FICK, OSCAR ARTHUR, Erecting Engineer, Westinghouse Electric and Mfg. Co., 716 Board of Trade Bldg., Boston, Mass.

FINDLEY, F. HERBERT, Engineering Department, Western Electric Co.; res., 6731 Parnell Ave., Chicago, Ill.

FISHBACK, FREDERICK R., Salesman, Electric Controller and Supply Co.; res., 7617 Linwood Ave., Cleveland, O.

FRANKENBERG, JOHN THEODORE, Chief Engineer, Providence Telephone Co., Providence, R. I.

FREUND, MORTIMER, Laboratorian, Yards and Docks Department U. S. Navy Yard; res., 116 W. 133d St., New York City.

FRIED, JOHN M., Student Cornell University; res., 109 Summit Ave., Ithaca, N. Y.

GARDETT, HELMUTH CLIFTON, Wiring Foreman, Pacific Electric Railway Co., 1826 21st St., Bakersfield, Cal.

GASSAWAY, FREDERICK STEUART, District Representative, Helios Mfg. Co., Bridesburg, Philadelphia, Pa.

GIBSON, DAVID GERRICK, Jr., Apprentice, Westinghouse Electric. Mfg. Co., Pittsburg, Pa.

GILCHREST, FRANCIS HARRIE, Assistant Superintendent of Installation, Western Electric Co., 259 South Clinton St., Chicago, Ill.

GLASSCO, GORDON BOND, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.

GRAH, EMIL, Electrical Engineer, 1310 Adams St., Toledo, O.

GREER, SAMUEL MILLER, Division Contract Agent, N. Y. & N. J. Telephone Co., 81 Willoughby St., Brooklyn, N.Y.

GRIFFIN, HANCOCK, Assistant to Manager Traction Department, General Electric Co., 44 Broad St., New York City.

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HALDEMAN, BERTRAND C., Engineer, B. and R. Electric and Telephone Mfg. Co., 3829 Euclid Ave., Kansas City, Mo.

HAMMOND, HAROLD ORVIS, Student, Columbia University; res., 203 W. 109th St., New York City.

HANSEN, ALFRED FREDERICK, Chief Operator, Central California Traction Co., 327 E. Washington St., Stockton, Cal.

HANSEN, MARVIN W., Electrical Contractor, 2455 Franklin Ave., Toledo, Ohio.

HARMON, JUDSON BINGHAM, Wire Chief's Assistant, New York Telephone Co., 55 Franklin St., New York City.

HARRIS, CHESTER R. R., Supervisor of Inspectors, Western Electric Co., 259 Clinton St.; Chicago, Ill.

HARVEY, THOMAS MIDDLETON, Chief Inspector, Southern Bell Telephone and Telegraph Co., Columbia, S. C.

HASTIE, ARTHUR GARFIELD, Apprentice, Westinghouse Electric and Mfg. Co.; res., 839 Rebecca Ave., Wilkinsburg, Pa.

HAWKINS, GUY DAVID, Equipment Man, American Telephone and Telegraph Co.; res., 809 Spruce St., Philadelphia, Pa.

HEIZMANN, LEWIS JOSEPH, Assistant Treasurer and Chief Engineer, Penn. Hardware Co.; res., 318 N. 5th St., Reading, Pa.

HERSHBERGER, FRANKLIN D., Draftsman, Western Electric Co., 259 So. Clinton St., Chicago, Ill.

HILTBRAND, ROBERT, Estimator, Cincinnati and Suburban Bell Telephone Co., 316 Vine St., Cincinnati, O.

HIPPLE, JOHN MERTON, Designing Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.

HOAG, WILLIAM HARVEY, Electrical Engineer, Consumers' Electric Co.; res., 1726 Bordeaux St., New Orleans, La.

HOAGLAND, HENRY C., Electrical and Mechanical Engineer, Illinois Traction System, Decatur, Ill.

HOFF, FRANK JOHN, Sub-station Foreman, Brooklyn Heights R.R. Co.; res., 346 54th St., Brooklyn, N. Y.

HOLCOMB, ANDREW DWIGHT Chief Operator, Postal Telegraph Cable Co., Atlanta, Ga.

HOOPER, WILLIAM LESLIE, Professor of Electrical Engineering, Tufts College; res., Somerville, Mass.

HORAN, PAUL, Toledo Railways and Light Co., 1223 Mason St., Toledo, O.

HOXIE, FREDERICK JEROME, Inspector, Associated Factory, Mutual Fire Insurance Co., Phenix, R. I.

HULETT, REXFORD EARL, Estimating Engineer, Western Electric Co., 259 So. Clinton St., Chicago, Ill.

HUMBLE, MERCER ALAN, Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg; res., 815 Franklin Ave., Wilkinsburg, Pa.

HYDE, WILLIAM ALBERT, Electrical Expert and Draftsman, Bureau of Ordnance, Navy Department, Washington, D. C.

INBUSCH, WALTER HENRY, Engineer, Pacific Telephone and Telegraph Co., Los Angeles, Cal.

JENNESS, EDWIN JEWELL, General Foreman, Western Electric Co., 259 So. Clinton St.; res., 5752 Madison Ave., Chicago, Ill.

JENNINGS, JAMES T., Electrical Engineer, Philadelphia and Reading Coal and Iron Co., Pottsville, Pa.

JEWETT, EDWIN HALE, Master Mechanic, Libbey Glass Co.; res., 326 Stickney Ave., Toledo, O.

JOHNSON, JOSEPH ALLEN, Assistant in Engineering Department, Ontario Power Co., Niagara Falls, N. Y.

KANMACHER, SAM HOUSTON, Electrical Engineer, General Electric Co.; res., 26 Jay St., Schenectady, N. Y.

KENDALL, HARRY COLE, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.

KERSHNER, BERTRAM MOTTER, Assistant Electrical Engineer, Southern Pacific Co., 1117 Flood Bldg., San Francisco, Cal.

KILMER, WILLIAM SAUTELLE, Illuminating Engineer, Bureau of Illuminating Engineers, 437 5th Ave., New York City.

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KIMBALL, WILLIAM FRANCIS, Assistant to F. C. Sargent, Malden Electric Co., 101 Linden Ave., Malden, Mass.

KING, MOSES, JR., Engineer, Western Electric Co., 463 West St.; res., 2 W. 88th St., New York City.

LAYTON, LEON DE PEW, Engineer, Central New York T. & T. Co., Syracuse, N. Y.

LEBLOND, EDMOND J., Engineering Department, Utah Light and Railway Co.; res., 217 So. 2d East, Salt Lake City. Utah,

LEQUESNE, CHARLES AUGUSTUS, JR., Assistant Electrical Engineer, New York Telephone Co., 15 Dey St., New York City.

LE TOURNEAU, EDWARD HAROLD, Tester, N. Y. C. & H. R. R.R. Co., Port Morris Power Station, New York City.

LILLARD, OGDEN WHITTIER, Electrical Engineer, Gould Storage Battery Co., 705 Monadnock Bldg., San Francisco, Cal.

LINCOLN, HARRY FOSTER, General Superintendent of Construction, Anglo-Newfoundland Development Co., Grand Falls, Newfoundland.

LINDSEY, WILLIAM DALES, Telephone Engineering Department, Western Electric Co., 463 West St., New York City.

LOF, ERIC ADOLF, Electrical Engineer, Western Electric Co.; res., 2273 Van Buren St., Chicago, Ill.

LOGAN, KIRK HAROLD, Service Inspector, New York Telephone Co.; res., 316 Argyle Road, Brooklyn, N. Y.

LONG, EBEN WILMER, Erecting Engineer, Crocker-Wheeler Co., Ampere, res., 27 No. 18th St., East Orange, N. J.

LOUGH, JAMES PEROT, Power Plant Inspector, New York Telephone Co., 15 Dey St., New York City; res., New Dorp, Staten Island.

LUNDGREN, GUS, Manager, Cherokee Electric Co., Cherokee, Ia.

MAASS, DANIEL, Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.

MACDONALD, JOHN ROBERT, Motor Operator, Anconda Copper Mining Co., 115 E. 4th St., Anaconda, Mont.

MALCOLM, GEORGE HOAG, Electrical Engineering Department, Otis Elevator Co.; res., 78 Warburton Ave., Yonkers, N. Y.

MALLETT, GEORGE OSCOR, Construction Foreman, General Electric Co., Schenectady, .N Y.

MARTIN, CHARLES BOYNTON, Transmission Engineer, N. Y. C. & H. R. R.R.; res., 220 Lincoln Road, Brooklyn, N. Y.

MARTZ, JOHN E., Superintendent and Manager, Seward Municipal Electric Light and Water Works, Seward, Neb

MAXWELL, WILLIAM ALEXANDER, Draftsman, Canadian Bridge Co., Ltd., Edmonton, Alberta. Can.

MCAFEE, ALLAN LINDSAY, Student, University of Minnesota; res., 552 Dayton Ave., St. Paul, Minn.

MCCAIN, PHILIP L., Tester, General Electric Co.; res., 2 Eagle St., Schenectady, N. Y.

MCKENZIE, JOHN, Chief Engineer, Blue Island Station, North Shore Electric Co., 134 Washington St., Chicago, Ill.

MICKLEY, THOMAS BENJAMIN, Assistant Supervisor, New York Telephone Co., 15 Dey St.; res., 153 E. 86th St., New York City.

MILLER, GEORGE J., Electro Chemist, Toledo Storage Battery Co.; res., 2419 Warren St., Toledo, O.

MILLER, WILFRED AMRAM, Designer, Hadaway Electric Heating and Engineering Co., 228 West Broadway; res., 21 E. 101st St., New York City.

MILLIKEN, HUMPHREYS, Operator, New York Edison Co., 38th St. and East River, New York City.

MITCHELL, HERMAN C., Engineering Department, Western Electric Co.; res., 6210 Princeton Ave., Chicago, Ill.

MORGAN, DANIEL, Consulting Electrical Engineer, Pittsburg Dredging Co., 604 Empire Bldg., Pittsburg, Pa.

MORGANSTERN, RALPH MORRIS, Morganstern, Ochiltree Co., 325 2d Ave.; res., 660 Maryland Ave., Pittsburg, Pa.

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MOSS, SANFORD ALEXANDER, Engineer Turbine Research Department, General Electric Co., Lynn, Mass.

MOYER, JAMES AMBROSE, Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City.

MUNRO, MADULL WATSON, Manager Electrical Department, A. & T. Burt, Ltd., Dunedin, N. Z.

MURMANN, FREDERICK J., Superintendent of Meter Department, Westchester Lighting Co., Mt. Vernon, N. Y.

MYERS, HARRY PORTER, Foreman of Armature Department, F. Bissell Co.; res., 262 Field Ave., Toledo, O.

NEWBAKER, CHARLES ATWOOD, Electrical Engineer, Sociedad Electrica de Arequipa, Ltd., Arequipa, Peru, S. A.

NEWBURY, FRANK DAVIES, Engineer, Westinghouse Electric and Mfg. Co.; res., 512 Kelly Ave., Wilkinsburg, Pa.

NIGHTINGALE, JOHN MERCER, Assistant Section Foreman Testing Department, General Electric Co.; res., 1110 Union St., Schenectady, N. Y.

NIMS, LESLIE WHITE, Assistant to Chief of Southern District, Compania Mexicana de la Luz y Fuerza Motriz, Mexico D. F., Mex.

NORTON, LAURENCE CLELAND, Salesman, F. Bissell Co.; res., 11 La Florence Flats, Toledo, O.

O'SHEA, ALEXANDER, Electrical Inspector, Government Printing Office, Washington, D. C.

PAIGE, AUSTIN JOHN, Telephone Engineer, Western Electric Co., Chicago, Ill.

PALMER, GEORGE WARE, JR., Electrical Engineer, Boston and Northern and Old Colony Street Railway Cos., 84 State St., Boston, Mass.

PARKER, LAURENCE MELVILLE, Electrical Worker, Illinois Traction System; res., Hotel Arion, Peoria, Ill.

PAUL, EARL WHEELER, Electrical Engineer, Duquesne Light Co.; res., 219 Swissvale Ave., Pittsburg, Pa.

POND, ALEMBERT LUCION, Travelling Engineer and Salesman, Fort Wayne Electric Works, 623 Marquette Bldg., Chicago, Ill.

POOLE, BURNELL, Engineering Department, New York Telephone Co., 15 Dey St., New York City; res., 113 Columbia Heights, Brooklyn, N. Y.

PORSKIEVIES, ANTHONY JOSEPH, Assistant to Designing Engineer, Crocker-Wheeler Co.; res., 379 Sixth Ave., Ampere, N. J.

PRENDERGAST, HENRY THOMAS, Arc Lamp Department, Toledo Railways and Light Co.; res., 409 Boston St., Toledo, O.

PULLEN, MYRICK WHITING, Student Iowa State College, Ames, Iowa; res., Onawa, Iowa.

RAINEY, PAUL MILLER, Engineer, Western Electric Co., 463 West St.; res., 672 Union Ave., New York City.

RANKIN, WILLIAM AYLMER, Electrical Engineer, Champion Copper Co., Painesdale, Mich.

RANNELLS, EDMUND BLAINE, Electrical Draughtsman, Edison Illuminating Co.; res., 188 State St., Brooklyn, N. Y.

REDEWILL, AUGUSTUS CASS, Tester, General Electric Co.; res., 104 Jay St., Schenectady, N. Y.

REEDER, CHARLES LEONARD, Consulting Engineer, 919 Equitable Bldg.; res., Arundel Apartments, Baltimore, Md.

RESOR, WILLIAM SETH, General Foreman, Construction Department, Chicago Telephone Co., 986 Washington Blvd., Chicago, Ill.

RICKETTS, JOHN WILLIAM, Superintendent of Light and Power, Oro Water Light and Power Co., Oroville, Cal.

ROBERTS, DAVID ALLEN, Partner, Philadelphia Electric Construction Co., 914 Filbert St., Philadelphia, Pa.; res., Moorestown, N. J.

ROEDDER, OTTO C., Consulting Engineer, 33 Klauprechst, Karlsruhe, Ger.

ROGERS, JOHN H., JR., Engineer and General Superintendent, Kansas City Home Telephone Co., 1018 Baltimore Ave., Kansas City, Mo.

ROGERS, SAMUEL HENNING, Chief Clerk, New York and New Jersey Telephone Co., 547 Clinton Ave., Brooklyn, N. Y.

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ROSS, JAMES DUNBAR, Student, Brooklyn Polytechnic Institute; res., 1263 Pacific St., Brooklyn, N. Y.

ROTH, LESTER, Chief Clerk, American Telephone and Telegraph Co., 158 Adams St., Chicago, Ill.

RUGG, HOWARD VAN, District Engineer, Westinghouse Electric and Mfg. Co., 2011 Market St., Philadelphia, Pa.

SAUER, MAX VEITCH, Assistant to Engineer, Ontario Power Co., Niagara Falls, N. Y.

SAWYER, ARTHUR RODNEY, Professor of Physics and Electrical Engineering, Michigan Agricultural College, Agricultural College, Mich.

SCHMIDLEY, WILLIAM ROBERT, Foreman of Meter Inspectors Union Electric Light and Power Co., 1244 Aubert St., St. Louis, Mo.

SCHUMAKER, JOHN STAUBLEY, Acting Superintendent Power Stations, Boston Elevated Railway Co., 439 Albany St., Boston, Mass.

SCOTT, WILLIAM DAVID, Equipment Engineer, Bell Telephone Co., 24 Seneca St., Buffalo, N. Y.

SHALDERS, ROBERT JAMES, Mechanical Engineer, Societe Anonyme du Gaz de Rio de Janeiro, Sao Paulo, Brazil, S. A.

SHARP, JOSEPH W., Line Foreman, Toledo Railway and Light Co.; res., 2224 Whitney Ave., Toledo, O.

SHEARER, ARTHUR GREGSTONE, Electrical Superintendent, Newcastle on Tyne E. S. Co., Ltd., Carville Power Station, Wallsend on Tyne, England.

SHOEMAKER, RICHARD WOOLSEY, Electrical Engineer, Federal Lead Co., Flat River; res., Farmington, Mo.

SHREWSBURY, LEWIS ALFRED, Chief Electrician, El Oro Mining and Railway Co., Ltd., El Oro, Mexico.

SIAN, JAMES RITCHIE SPARKMAN, JR., Machinery Salesman, Kamiuski Machinery Co., Georgetown, S. C.

SIMMONS, BENJAMIN FRANKLIN, Superintendent, Holyoke Water Power Co., Holyoke, Mass.

SIMMONS, GEORGE MATTHEWS, Foreman Erecting Department, Westinghouse Electric and Mfg. Co., New York City.

SLACK, GEORGE, Engineer, Clark Montana Realty Co., Missoula; res., Bonner, Mont.

SMITH, CHESTER MARTIN, Engineering, Department, Western Electric Co.; res., 498 Leland Ave., Chicago, Ill.

SMITH, CLINTON BESLEY, Electrical Repairman, Helena Power Transmission Co., Helena; res., Hauserlake, Mont.

SMITH, WILLIAM FERDINAND, General Construction Foreman, Pacific Electric and Los Angeles Inter Railways, Los Angeles, Cal.

SNIDER, OTHO CARLETON, Vice-president and General Manager, Kansas City Home Telephone Co., 1018 Baltimore Ave., Kansas City, Mo.

SOPER, FRANK CLEMENT, Telephone Engineer, Western Electric Co., 463 West St., New York City; res., 26 N. 19th St., East Orange, N. J.

STACK, MICHAEL LEO, Construction Department, Consolidated Railway Co.; res., 110 De Witt St., New Haven, Conn.

STEARNS, RAY, Designing Engineer, General Electric Co.; res., 1007 Nott St., Schenectady, N. Y.

STECKEL, ABRAM PETERS, Engineer, Buffalo Smelting Works; res., University Club, Buffalo, N. Y.

STEPHENS, ARTHUR PORTER, Chief Electrician, Dan River Power & Mfg. Co., Danville, Va.

STEPHENS, CHARLES, Arc Lamp Engineer, Westinghouse Electric and Mfg. Co.; res., 1108 Center St., Wilkinsburg, Pa.

STERNBERG, CARL, Student, University of Minnesota; res., 99 Nicollet St., Minneapolis, Minn.

STEWART, JAMES A., Superintendent of Plant, New York and New Jersey Telelphone Co., 15 Dey St., New York City.

STOCK, WILLIAM ANDREW, Draftsman, Western Electric Co.; res., 2834 W. Monroe St., Chicago, Ill.

STRAUSS, JULIUS, Telephone Engineer, New York and New Jersey Telephone Co.; res., 322 E. 90th St., New York City.

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TAYLOR, PHILIP SHERIDAN, Electrical Engineer, Pacific Electric Railway Co.; res., 451 South State St., Los Angeles, Cal.

TERRY, JOHN CHARLES, Sales Engineer, J. L. Schufeman Co., 70 W. Jackson Blvd.; res., 2206 Washington Blvd., Chicago, Ill.

THEOBALD, CHARLES EDWIN, Electrical Engineer, Plant Department, New York Telephone Co., 15 Dey St., New York City.

THOMPSON, FORD DE CAMP., in charge of Engineering Inspection, Western Electric Co., New York; res., 28 Vernon Ave., Brooklyn, N. Y.

THOMPSON, GEORGE W., Salesman, West inghouse Electric and Mfg. Co.; res., Hazleton, Pa.

TIMMERMAN, RAY, Assistant Engineer Meter Department, Telluride Power Co., Provo, Utah.

TITUS, WILLIAM ANDREW, Assistant Superintendent of Installation, Western Electric Co.; res., 182 Winthrop Ave., Chicago, Ill.

TOOKER, HARRY C., Foreman Sub-station, N. Y. C. & H. R. R.R.; res., 598 Bergen Ave., Bronx, N. Y.

TRAVIS, THURLOW, Electrical Foreman, N. Y. C. & H. R. R.R., Port Morris Power House, 142d St. and East River, New York City.

VANDERZANDE, JAN, Electrical Engineer, United Railroads of San Francisco, San Francisco, Cal.

VAN WYCK, WILLIAM PATERSON, Chief Inspector, Engineering Department, N. Y. & N. J. Telephone Co., 26 Cortlandt St., New York City.

VORUM, ANDREW H., Equipment Engineer, Western Electric Co.; res., 505 W. 62d St., Chicago, Ill.

WAGNER, WILLIAM ALFRED, Engineer, Plant Department, New York Telephone Co.; res., 55 W. 127th St., New York City.

WALKER, JOHN LOOMIS, Central Office, Telephone Equipment Engineer, Western Electric Co., Chicago, Ill,

WARNER, GEORGE BIDDULPH, Salesman, Westinghouse Electric and Mfg. Co., 716 Board of Trade Building, Boston, Mass.

WEST, CHARLES, General Mangager, Consolidated Telephone Companies of Pennsylvania, Allentown, Pa.

WEST, GARNET EVERSLEY, Draughtsman, Stanley G. I. Electrical Mfg. Co.; res., Woodlawn Inn, Pittsfield, Mass.

WHITFIELD, GEORGE HILLMAN, Mechanical and Electrical Engineer, Virginia Pass. and Power Co., Richmond, Va.

WICHUM, VICTOR, Traffic Department, New York Telephone Co., 15 Dey St., New York City; res., 241 Covert St., Brooklyn, N. Y.

WILDER, EDWARD LYMAN, Engineer, Westinghouse Electric and Mfg. Co.; res., 312 East End Ave., Pittsburg, Pa

WILKES, DANIEL ARTHUR, Cable Inspector, Potomac Electric Power Co.; res., 43 M St. N. W., Washington, D.C

WILKERSON, FRANK B., Engineering Department, Western Electric Co.; res., 557 W. 65th St., New York City.

WILKINSON, WILLIAM BARRETT, Wire Chief, Chicago Telephone Co.; res., 484 W. Adams St., Chicago, Ill.

WILLIAMS, JOHN STUART, Designing Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa,

WILLISON, CHARLES DONALD, Electric Service Supplies Co.; res., 158 So. Leavitt St., Chicago, Ill.

WITHERSPOON, THOMAS DWIGHT, Electrical Engineer, Toledo Furnace Co.; res., 2425 Cherry St., Toledo, O.

WOLCOTT, VARANAS ARTHUR, Electrical Engineer, General Electric Co.; res., 616 Smith St., Schenectady, N. Y.

WOODYATT, JAMES BLAIN, Engineering Apprentice, Canadian Westinghouse Co., 14 Duke St., Hamilton, Ont.

YOUNG, CHARLES WILLIAM, Draughtsman, United Railways Co.; res., 1708 N. Taylor Ave., St. Louis, Mo.

YOUNG, WALTER E., Assistant to Data Engineer, Canadian General Electric Co., Ltd., 14 King St. East; Toronto, Ont.

Total, 229.

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Applications for Election

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the Secretary before August 23, 1907.

6561 J. C. Pennie, Montclair, N. J.
6562 A. E. Seelig, New York City.
6563 F. V. Underwood, Birmingham, Ala.
6564 H. D. Randall, Seattle, Wash.
6565 H. S. De Lancie, Philadelphia, Pa.
6566 J. B. Heim, Vallejo, Cal.
6567 C. T. Bowring, Wilkinsburg, Pa.
6568 W. L. Johnson, Middleboro, Eng.
6569 H. D. Symons, Manchester, Eng.
6570 G. S. Iredell, Austin, Texas.
6571 A. L. Black, New Orelans, La.
6572 L. H. Conklin, Connellsville, Pa.
6573 J. deG. Beaubein, Wilkinsburg Pa.
6574 Ferdinand Stern, New York City.
6575 N. P. F. Death, Toronto, Ont.
6576 E. M. Ashworth, Toronto, Ont.
6577 Kozo Tada, Kyoto, Japan.
6578 Thos. Cooper, Philadelphia, Pa.
6579 C. L. Collins, Niagara Falls, N. Y.
6580 G. A. Hearn, Napa, Cal.
6581 C. E. Lucke, New York City.
6582 F. B. Jones, Salt Lake City, U.
6583 A. J. Horton, New York City.
6584 L. B. Magid, Tallulah Lodge, Ga.
6585 H. Graftio, St. Petersburg, Russia.
6586 C. W. Jones, Stamford, Conn.
6587 J. S. Myers, Atlanta, Ga.
6588 A. C. Connolly, Mexico, D. F.
6589 V. T. Brigham, Lafayette, Ind.
6590 W. E. Foss, Boston, Mass.
6591 F. E. Murphy, Wilkinsburg, Pa.
6592 M. M. Goldenstein, Mil., Wis.
6593 F. T. Stocking, Toronto, Ont.
6594 R. E. Robinson, Charleston, S. C.
6595 F. S. Lewis, Cleveland, Ohio.
6596 Spencer Jewkes, Launceston, Tas.
6597 E. L. Jackson, Hammonton, N. J.
6598 G. F. Leake, Memphis, Tenn.
6599 Gustak Baldauf, Berlin, Germany.
6600 W.R.W.Griffin, Canandaugua, N Y
6601 A. J. Marshall, New York City.
6602 T. W. Denison, New York City.
6603 T. F. Morris, McKeesport, Pa.
6604 J. C. Crowell, Altanta, Ga.
6605 C. A. Davis, New York City.
6606 H. R. Wilde, Puebla, Mexico.
6607 E.E.Pendray, Cape Girardeau, Mo.
6608 J. L. Longino, Norfolk, Va.
6609 J. F. Carl, Colgate, Cal.
6610 H. B. Noyes, Omaha, Neb.
6611 C. M. Bliven, San Francisco.
6612 Antonio Cosme, Porto Rico.
6613 L. C. Coller, New York City.
6614 H. F. Strickland, Toronto, Ont.
6615 E. F. Bliss, Schenectady, N. Y.
6616 K. C. Ogden, New York City.
6617 L. S. Nelson, Schenectady, N. Y.
6618 F. M. Hibben, Cleveland, Ohio.
6619 T. S. Hemenway, Buffalo, N. Y.
6620 E. G. Reed, Wilkinsburg, Pa.
6621 L. St. D. Roylance, San Fran., Cal.
6622 H. D. Garretson, Buffalo, N. Y.
6623 Klas Weman, Buffalo, N. Y.
6624 E. H. Acton, Wilkinsburg, Pa.
6625 R. C. Graham, Meeker, Colo.
6626 C. N. Thorpe, Chicago, Ill.
6627 Wm. Siebenmorgan, Westfield, N.J.
6628 E. G. Williams, Weehawken, N. J.
6629 P. H. Honold, Port Wash., Wis.
6630 Emil Monori, Schenectady, N. Y.
6631 H. G. Edwards, Cincinnati, O.
6632 J. W. Skinkle, Chicago, Ill.
6633 Isador Kitsée, Philadelphia, Pa.
6634 Olaf Barge, Kristiania, Norway.
6635 Leonard Day, New York City.
6636 D. G. Ross, Toronto, Ont.
6637 D. S. Wegg, Jr., Provo, Utah.
6638 H. J. Cooper, Weston, Mass.
6639 George Handlong, New York City.
6640 Isaac Levinson, New York City.

Total 80.

Application for Transfer

Recommended for transfer by the Board of Examiners, June 7, 1907.

Any objection to this transfer should be filed at once with the Secretary.

J. H. Klinck, commercial engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.

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Personal

MR. LOUIS T. GRANT has severed his connection with Grant and Co. Ltd., of Manila, P. I., and assumed the practice of consulting engineer.

MR. SIMON B. STORER, formerly with the Niagara, Lockport and Ontario Power Company, has opened an office at Syracuse, N. Y., as a consulting engineer.

MR. CHARLES P. MERRILL has left the employ of the United States Signal Corps, and is now associated with the Dean Electric Company, Elyria, Ohio, in the cable department.

MR. W. C. SHARP has resigned from the New York Edison Company and accepted the appointment of superintendent of the Des Moines Edison Light Company, Des Moines, Iowa.

MR. P. G. TEN EYCK, former treasurer of the Federal Railway Signal Company, has been elected vice president of the company, with change of quarters from Troy, to Albany, New York.

MR. FREDERICK P. FISH has resigned the presidency of the American Telegraph and Telephone Company, and resumes the practice of the law with his old firm, at Boston and New York.

MR. WILLIAM M. JOY has left the Trinidad Electric Company, Ltd., and is at present engaged in work connected with the consolidation of the lighting and railway properties at San Juan, P.R.

MR. FRED T. CRAIG has finished the construction of the Sultepec Light and Power Company's plant, and left Temascaltepec, July 1, to accept a position with the Federal Engineering Company. of Mexico.

MR. FRED. M. LEGE, JR. is now general manager of the Brush Electric Light and Power Company of Galveston Texas, instead of the Allis Chalmers Company, as reported in the May Proceedings.

MR. C. A. MUDGE, formerly with the Electric Dynamic Company of New York City, is now connected with the railway engineering department of the General Electric Company at Schenectady, N. Y.

MR. E. H. RUPE, formerly with the Kellogg Switchboard and Supply Co., of Chicago, has accepted an appointment as superintendent with the Chandelier and Art Brass Works, of Richmond, Ind.

MR. G. W. BROWN has resigned from the Westinghouse Electric and Manufacturing Company, to accept a position with the Lexington Railway Company, of Lexington, Kentucky, as master mechanic.

MR. H. LEVAQUE WILLS, formerly contract agent for the Georgia Railway and Electric Company of Atlanta, is now engaged with the Savannah Lighting Company, as general manager, at Savannah, Ga.

MR. C. J. KIEFER is now connected with The Reliance Engineering Company, consulting electrical and mechanical engineers, Cincinnati, O., whose specialty is the building of interurban traction roads.

MR. H. M. BEUGLER has resigned from the employ of Ford, Bacon and Davis, as superintendent of railways, and is now with Dodge and Day, Drexel building, Philadelphia, as general superintendent of construction.

MR. F. E. WHITNEY has resigned his position as master mechanic of the West Penn. Railway Company, Connellsville, Pa., to accept appointment as assistant general manager of the same company at Philadelphia.

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MR. J. N. CADBY received the degree of Electrical Engineer from the University of Wisconsin, on the presentation of a thesis entitled, "The Design, Construction, Operation, and Test of a Railway and Lighting Sub-station."

MR. I. R. EDMANDS, formerly electrical engineer for the Union Carbide Company, and superintendent of its plant at Sault Ste. Marie, Michigan, now has his headquarters at 157 Michigan Avenue, Chicago, as works manager for the same company.

MR. R. H. HENDERSON, formerly assistant superintendent of the Newark Works of the Westinghouse Electric and Mfg. Co., has been appointed superintendent of the Bloomfield works, of the Westinghouse Lamp Co., at Bloomfield, N. J.

MR. W. A. EKBERG, has left the H. W. Johns-Manville Company, to engage in business for himself as manufacturer's agent of electrical materials, and as Pacific Coast representative for several eastern manufacturers of electrical apparatus.

MR. FRANK WENNER, instructor in physics in the University of Pennsylvania for the past ten years, is now first assistant in the section of resistances and electromotive forces of the National Bureau of Standards, Washington, D. C.

MR. IRVING W. PHILLIPS, for the past eighteen months assistant to the superintendent of the North Mountain Power Company of Eureka, California, has been promoted to superintendent of power plant, at Junction City, Trinity County, California.

MR. LYNNE W. EDDY, member of the 1907 E. E. class of the University of Minnesota, has removed to 1677 Ogden Avenue, Chicago, Ill., to accept a position in the students' course of the Western Electric Co., in its power apparatus shops at Hawthorne, Illinois.

MR. C. W. JOHNSON, for the past three years general superintendent of the shops of Allis-Chalmers-Bullock, Ltd., at Montreal, has left that company, and is now attached to the works staff of the Westinghouse Electric and Mfg. Company, at Pittsburg, Pa.

MR. FRANCIS J. CHESTERMAN has left the engineering department of the American Telephone and Telegraph Company of Boston, Massachusetts, and has entered the engineering department of the New York Telephone Company, 15 Dey Street, New York City.

MR. JOSEPH P. MANYPENNY, of Philadelphia, formerly connected with the Keystone Electrical Instrument Company, is now with the Philadelphia Electric Construction Company, 914 Filbert Street, Philadelphia, as representative of this company for its many agencies.

MR. WILLIAM. D. MARKS, Ph. B.C.E., having after eighteen months in the service of the Corporation Counsel of New York City been continued in office as a principal expert in gas and electricity for New York City, has removed his offices to 623 Park Row building, New York City.

MR. P. A. MOSSAY, formerly in the engineering department of the British Westinghouse Electric and Mfg. Co., has been obliged on account of ill health to leave Manchester, and is now chief engineer for the Nordeutsche Maschines und Armaturen-Fabrik Company at Bremen, Germany.

MR. HENRY J. BLAKESLEE, is at present in the employ of the City of Syracuse as superintendent of Bureau of Gas and Electricity; a position resulting from a recent state law known

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as the Hammond Bill, which went into effect July 1. His address is Room 111 Court House, Syracuse, N. Y.

MR. C. OTTO VON DANNENBERG has left Columbia University, Washington, D. C. to accept appointment as electrician-in-charge in department of construction and repair, Pensacola navy yard, The position was obtained after a competitive examination held at the New York navy yard.

MR. E. C. BACOT, for five years chief electrician of the Great Northern Power Company of Duluth, Minnesota, having had charge of the design and installation of its entire plant and apparatus, will, after his vacation, be associated with the Bibb Power Company, of Macon, Georgia, as chief electrician and designing engineer.

MR. B. N. JONES, of the Otis Elevator Company, who had charge of the company's new manufacturing plant as constructing engineer, during its erection at Buffalo, N.Y., has been appointed assistant general superintendent of the manufacturing and constructing department of the company, with headquarters at 17 Battery Place, New York City.

MR. HARRY F. REYNOLDS, who has for the past six years been engaged in electrical engineering throughout the middle west, with offices at Marion and Indianapolis, Ind., has disposed of his interests in that locality. He has opened an office at 656 Empire Building, Seattle, Washington, and will engage in engineering and contracting on the Pacific Coast.

MR. WILHELM BAUM, who has been engaged for three and a half years with the engineering department of the General Electric Company, at its Pittsfield works, (formerly Stanley-G. I. Electric Mfg. Co.) in the design of generator, and alternating motors, has been transferred to the Schenectady works to take up general commercial engineering.

MR. C. R. PRATT, former associate with Mr. Frank J. Sprague, in the Sprague-Pratt electric elevator, also with the Otis Elevator Co., and the Marine Engine and Machine Co., has removed to 1123 Broadway, where he continues his practice as consulting engineer on electric elevator work. He is at present designing a line of high-speed electric traction elevators.

MR. ARTHUR J. FARNSWORTH has recently accepted a position with the Stone and Webster Engineering Corporation as superintendent of construction on extensive additions to the plant of the Jacksonville Electric Company of Jacksonville, Florida. Mr. Farnsworth will have charge of the local office of the company, and expects to remain in the south for at least six months during the progress of this work.

MR. WILLIAM E. MITCHELL, formerly with the Sao Paulo Tramway Light and Power Company, has accepted a position as electrical engineer of the Bahia Tramway, Light and Power Company, of Bahia, Brazil, which has taken over the old Siemens and Halske electric tramway, and is completely renovating and extending this system. A new power house of 1050 kw. capacity is being erected. It is a unique plant for South America, in that the prime movers are Crossley four-cylinder, 500 h.p. gas engines, direct-connected to Dick-Kerr 350 generators.

Books Received

The following volumes have been received from the McGraw Publishing Company and placed in the Library of the Institute:

ELECTRIC STREET RAILWAYS. A description of the generation, transmission and utilization of electric currents in connection with electric street railways. By Edwin J. Houston and A. E. Kennelly. Second

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edition. 373 pages, 162 illustrations. New York, McGraw Publishing Co. Price, $1 net.

Chapter I.—Introduction. II.—Early History of the Electric Railway. III.—Elementary Electric Principles. IV.—The Motor. V.—Cars and Car Trucks. VI.—Electric Lighting and Heating of Cars. VII.—Controllers and Switches. VIII.—Trolleys. IX.—Trolley Line Construction. X.—Track Construction. XI.—Electrolysis. XII.—Switchboards XIII.—Generators and Power-houses. XIV.—Operation and Maintenance. XV.—Storage-battery System. XVI.—Electric Locomotives. XVII.—High Speed Railway Service.

Practical Electric Railway Handbook. Engineering facts, figures and dimensions for electric railways. By Albert B. Herrick. Handsomely bound in leather. Second edition, enlarged. 460 pages, 329 illustrations. New York, McGraw Publishing Co. Price, $3 net.

Section I.—General Tables. Section II.—Testing. Section III.—The Track. Section IV.—The Station. Section V.—The Line. Section VI.—The Car-house. Section VII.—The Repair Shop. Section VIII.—The Equipment. Section IX.—The Operation.

A Graphical Treatment of the Induction Motor. By Alexander Heyland. Translated from the second edition by G. H. Rowe and R. E. Hellmund. The object of this book is to explain the use of the circle diagram, which the author has found effective in the testing room for comparing the calculated values with results obtained from tests, thus showing at a glance the commercial excellence and main properties of a motor. Cloth, 50 pages, 28 diagrams. New York, McGraw Publishing Co. Price, $1 net.

Contents.—Introduction.—General Theory—Diagrams of the Induction Motor; Current, Field and Circle—Determination of Input, etc., from Diagram; Friction and Iron Losses, Copper Losses, Electrical Input, Torque, Output, Slip, Efficiency—Practical Application of the Diagram—Examples; 2, 7 and 12 h.p. Motors—Induction Motor as Generator—Single-phase Motor."

The Induction Motor; Its Theory and Design. Set forth by a practical method of calculation. By Henri Boy de la Tour. Translated from the French by C. O. Mailloux. Second edition, corrected. 200 pages, 75 illustrations. New York, McGraw Publishing Co. Price, $2.50 net.

This work is intended to elucidate the theory of the Induction Motor, and to facilitate its design by a practical method of calculation which is at once simple, ingenious and effective. The object of the book is stated by the author in his preface as follows: "We have wished to come to the assistance of those who have not had occasion to take special courses, and who, owing to the lack of sufficiently extended knowledge, have not derived very much profit from all that has appeared in the scientific papers. We have, therefore, endeavored to give a complete study of the Induction Motor, and to explain at length, all the peculiarities of its operation, while remaining within the bounds of elementary mathematics." The book will be useful to all who desire information regarding the peculiarities of the Induction Motor, especially those who desire to study the effect of changes or modifications in design and proportions on the performance of the Induction Motor and its adaptability to different purposes. The work will be especially valuable to the designer who is looking for relatively simple rules and methods, whereby the modifications in design and in details necessary to meet certain requirements may be predetermined.

(To be continued.)

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Atlanta............Jan. 19, '04	A. M. Schoen.	W. R. Collier.	
Baltimore.........Dec. 16, '04	J. B. Whitehead.	C. G. Edwards.	2d Friday.
Boston............Feb. 13, '03	H. E. Clifford.	C. H. Porter.	3d Wednesday
Chicago.................1893	P. B. Woodworth.	H. R. King.	1st Tuesday after N. Y. meeting.
Cincinnati.........Dec. 17, '02	G. A. Wessling.	A. C. Lanier.	
Columbus.........Dec. 20, '03	R. J. Feather.	H. L. Backman.	1st Monday.
Ithaca............Oct. 15, '02	E. L. Nichols.	H. H. Norris.	1st Friday after N. Y. meeting.
Minnesota..........Apr. 7, '02	H. J. Gille.	Barry Dibble.	2d Monday after N. Y. meeting.
Pittsburg..........Oct. 13, '02	H. W. Fisher.	H. D. James.	2d Tuesday.
Pittsfield..........Mar. 25, '04	Gilbert Wright.	S. H. Blake.	3d Thursday.
Philadelphia.......Feb. 18, '03	W. C. L. Eglin.	H. F. Sanville.	2d Monday.
San Francisco......Dec. 23, '04	C. L. Cory.	A. H. Babcock.	
Schenectady.......Jan. 26, '03	D. B. Rushmore.	E. E. F. Creighton.	2d Wednesday.
Seattle............Jan. 19, '04	C. E. Magnusson.	W. S. Wheeler.	3d Saturday.
St. Louis..........Jan. 14, '03	A. S. Langsdorf.	J. H. Finney.	2d Wednesday.
Toledo............ June 3, '07	W. G. Nagel.	Geo. E. Kirk.	
Toronto..........Sept. 30, '03	R. G. Black.	L. W. Pratt.	2d Friday.
Urbana...........Nov. 25, '02	Morgan Brooks.	M. K. Akers.	1st Wednesday
Washington, D. C...Apr. 9, '03.	P. G. Burton.	Philander Betts.	1st Thursday.
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Iowa State College..Apr. 15, '03	F. A. Fish.	Adolph Shane.	1st Wednesday.
Lehigh University..Oct. 15, '02	A. W. Lawson.	M. T. Saldana.	3d Thursday
Montana Agr. Col. .May 21, '07	F. S. Lorentz.	J. A. Thaler.	1st Friday.
Ohio State Univ....Dec 20, '02	H. C. Bartholomew	F. E. Beutler	Every Tuesday evening
Penn. State College.Dec 20, '02	E. W. Nick.	S. W. Price.	Every Wednesday
Purdue University..Jan. 26, '03	C. P. Matthews.	J. W. Esterline.	Every Tuesday.
Syracuse University Feb. 24, '05	W. P. Graham	R. A. Porter.	1st and 3d Thursdays.
Univ. of Arkansas..Mar 25, '04	W. B. Stelzner.	K. A. Reed.	1st & 3d Tuesdays
Univ. of Colorado..Dec 16, '04	A. M. Gregg.	H. S. Buchanan.	1st and 3d Wednesdays
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Univ. of Missouri...Jan 10, '03	H. B. Shaw	H. D. Carpenter.	1st and 3d Fridays
Univ. of Montana..May 21, '07	Robert Sibley.	S. R. Inch.	1st Thursday.
Univ. of Wisconsin.Oct. 15, '02	F. M Conlee.	J. W. Shuster.	4th Thursday.
Washington Univ...Feb 26, '04	A. S. Langsdorf	W. E. Bryan.	1st Wednesday
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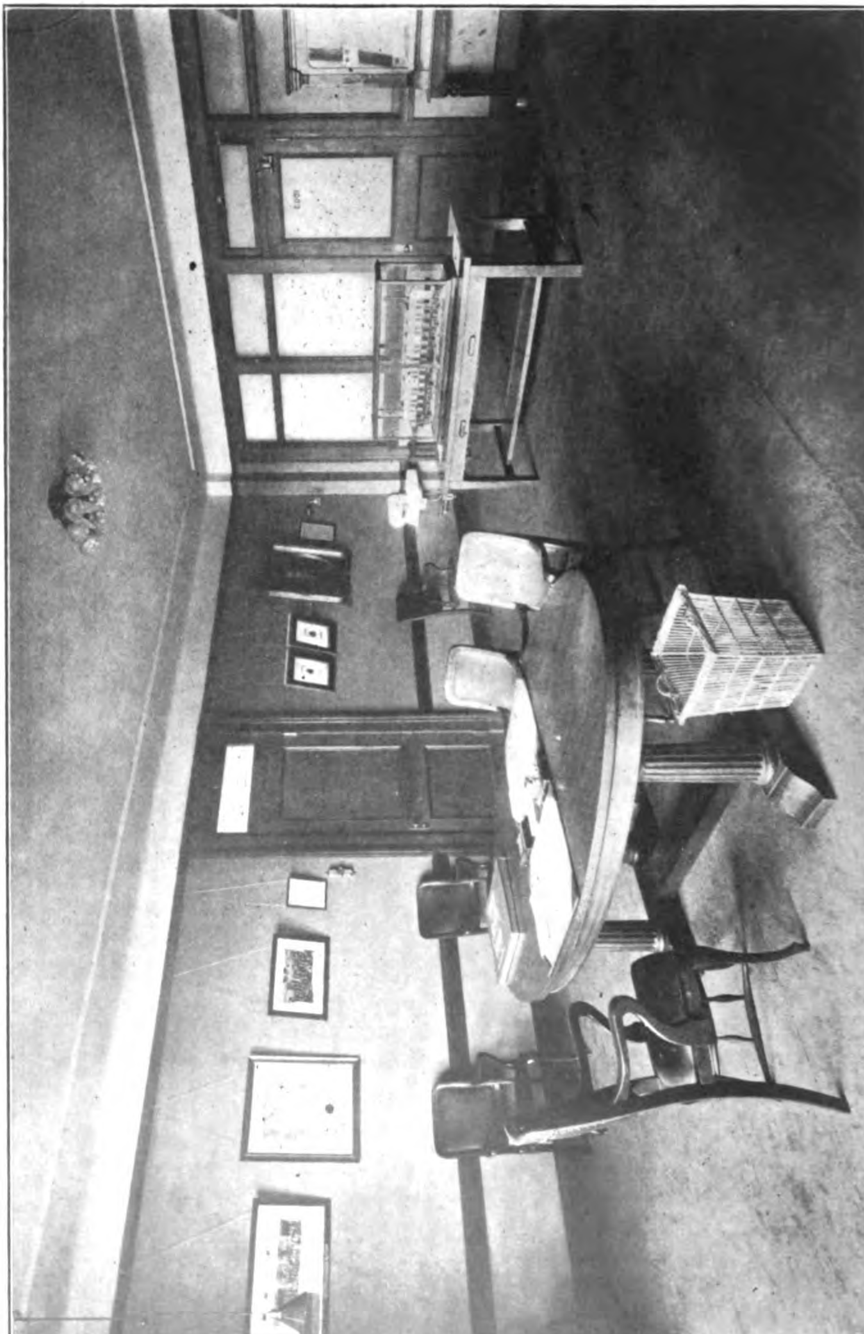

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OF THE

American Institute

OF

Electrical Engineers.

Published monthly at 33 W. 39th St., New York, under the supervision of

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Vol. XXVI. **August, 1907.** No. 8.

Engineering Statesmen

THE theory that lawyers only are suitable material for high political offices is slowly crumbling, and there has been a tendency to suggest financiers or business men in order to get better results.

The engineer has been overlooked, upon the supposition that he is a mere specialist, in fact a "hired man." Yet engineers are entering upon high administrative and executive duties, and have the valuable faculty of doing things, and usually avoiding scandalous methods. In his address at the dedication of the Engineers' Building, printed in full in the April issue of the Proceedings, President Hadley made a strong plea in the direction of public duty on the part of the engineer. He stated that "there are three professions today which do not regard themselves as servants, but masters—the financier, the journalist, and the politician." This address of President Hadley is worthy of serious consideration by every engineer, and it should be not only read, but put into practice. President Sheldon also touched upon a similiar line of thought when he pointed out the thorough manner in which engineers plan for the future. Perhaps no better example of this is apparent today than the vast engineering project of the Pennsylvania Railroad, which combines tunneling under a part of New Jersey, the Hudson River, Manhattan, the East River and a portion of Long Island. For many years the executive management of this great corporation has been in the hands of engineers who have continued to receive strong financial support in their gigantic plans.

Written Discussion

MEMBERS should continually keep in mind their privilege of contributing written discussions on papers presented at any meeting of the Institute, and printed in the PROCEEDINGS. It has been found practically impossible to print papers for general distribution in advance, and in most cases the best that can be done is to have them available at the meetings. Distant members who are interested in any paper announced for presentation may obtain copies by applying to the office. Written discussion on such papers if mailed within a month, and found to be acceptable, may be incorporated in the PROCEEDINGS. The membership now extends throughout the world, and it is impossible for any committee or individual to invite a discussion from all engineers who have had experience in the particular branch of work to which a paper pertains. The membership should appreciate the great amount of work which is being constantly done by committees at considerable personal sacrifice, and wherever

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possible should supplement this work by individual effort for the general good of the profession. Engineering practice varies in different parts of the world, and emergencies frequently arise which call for the exercise of ingenuity to meet unusual conditions. A record of methods adopted may thus become of general interest and its publication will redound to the credit of the originator.

References

SUFFICIENT care is not exercised in the matter of references either by candidates for election or for transfer, or by the members referred to. Members occasionally affix their signatures to an application blank, upon the request of a mutual friend, and a little later when the usual inquiry-form is received from the secretary, reply that the applicant is unknown to them, and that there must be some mistake. The signature proves that the application was endorsed by request, and that the incident was probably forgotten. If proper inquiry were made at the time, the circumstances would in most cases be so fixed in the mind that the reference could make a suitable reply. Applicants are also frequently careless in the selection of references. In one case a well-known scientist and professor who was referred to was much chagrined because he could not recall the applicant's identity. Upon investigation it appeared that the applicant had listened to a lecture by the professor. An applicant for transfer who could give but three out of the five references required, suggested that the other two might be selected from the membership at large. Proper care should be exercised in the selection of qualified references, as applications for election or transfer are delayed in many instances because it appears to be impossible to elicit suitable information. Careful reading of the instructions printed on the forms would obviate many of the difficulties which arise in connection with elections and transfers.

VOLUME XXV covering the year 1906 is now being distributed. Much difficulty has been avoided in foreign shipments by its weight having been brought within the postal limit of four pounds and six ounces. Owing to occasional local charges at distant points it has been impossible to make complete prepayment in all cases, which has given rise to complaints that could not be provided against. Shipment by express to foreign countries is imperative where the weight of the volume exceeds the postal limit, and the duties and sundry petty charges cannot always be determined in advance. Volumes for members in the United States will this year be shipped in bulk to cities and the larger towns and there distributed by local messengers, who will obtain and return receipts signed by the person to whom the package is delivered. It is believed that this system of delivery will be cheaper and more satisfactory than any yet tried. If any charge is made for delivery, the fact should be reported to the secretary immediately.

THE Founders' agreement requires that the Institute shall pay off its indebtedness of $180,000 in twenty installments of $9000 each, with interest upon the unpaid balance at the annual rate of four per cent. beginning July 1, 1906. Two annual installments having been previously paid, the Board of Directors at its meeting July 26, 1907 voted to make an advance payment of $36,000 which has since been done. The balance of the Land, Building and Endowment Fund on deposit August 1, after drawing this check was $53,402.60. At the meeting of the Board of Directors August 30, 1907, another payment of $45,000 was authorized, which will anticipate all installments actually required by the agreement up to 1916.

THE next New York meeting of the Institute will be held in the Auditorium, Engineers' Building, on Friday, October 11, at 8.15 p.m.

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Committee on Local Organizations—Annual Report Submitted to the Board of Directors, May 21, 1907

The Committee on Local Organizations would submit the following report on the Branch situation and of the work of the committee during the last year.

There are at present a total of 33 Local Organizations included under the head of Branches, University Branches, and Student Meetings. Of these, 17 are organized in connection with educational institutions, reaching the student membership; the remaining 16 are located in cities as centers of electrical interest for the Members and Associates in their territory. There have been but few additions or changes during the year in the above number of Local Organizations. The University Branch at the University of Illinois, having the number of Members and Associates required by the By-laws, has, by action of the Board of Directors, been made a Branch.

Student Meetings have also, by the approval of the board, been organized as follows:

University of Maine, December 26, 1906.

Montana Agricultural College, March 29, 1907.

The question of the adoption of a student pin and the design for such a pin were submitted to the Board of Directors and approved. These pins are now in the process of manufacture and will be available at the beginning of the next term for students desiring them.

At the beginning of the year there seemed to be a lack of definite understanding as to the publication in the PROCEEDINGS of original papers presented at the Branches. A conference on the matter was held with the Editing Committee, as a result of which it was decided to publish meritorious papers read before the Branches, and announcement to that effect was made in the December PROCEEDINGS.

Your committee feels that a reference should be made to the help afforded by the Branches in obtaining a vote for the revised Constitution. The cooperation of the Branches was enlisted for this purpose and a direct appeal to vote was made by the managers of the different local organizations to their membership. If a large enough vote is obtained on the Constitution for decisive action, considerable credit, we feel, should be given to the Branches. The Institute should also make note of the value of such organizations as a means of reaching a scattered membership.

The work done by the Branches themselves in the holding of engineering meetings and in the presentation and discussions of papers has undoubtedly been more successful this year than ever before. The following table of statistics will show, to some extent, the activities in this direction during the year:

	No. of meetings since Sept. '06.	Average attendance.	No. of original papers.
Atlanta	—	—	—
Baltimore	7	45	7
Boston	7	117	6
Chicago	5	95	5
Cincinnati	5	20	4
Columbus	7	15	1
Minnesota	10	40	12
Pittsburg	7	73	4
Pittsfield	6	27	3
Philadelphia	7	73	12
San Francisco	—	—	—
Schenectady	28	275	18
Seattle	5	17	3
St. Louis	7	25	5
Toronto	3	28	—
Washington, D. C.	4	44	—
Cornell University	8	130	4
Iowa State College	13	25	10
Lehigh University	8	40	20
Purdue University	12	100	7
Syracuse University	12	20	9
Univ. of Wisconsin	6	60	5
Univ. of Illinois	8	62	2
Worcester Poly. Inst.	7	46	11
Armour Institute	9	30	—
Ohio State Univ.	1	18	—
Penn. State College	—	—	—
Univ. of Arkansas	12	30	—
Univ. of Colorado	—	—	—
Univ. of Michigan	—	—	—
Univ. of Missouri	10	20	—
Washington Univ.	3	8	—

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It is evident from the above table that the Branches are carrying out the work which was the idea of their foundation. They have practically all been in existence for three or four years; the first flush of enthusiasm that may have existed at their formation has had time to cool; the leaders who were responsible for the starting of a Branch have, in most cases, passed on the work to other hands; and the fact that the work continues to flourish and the interest remains unabated, shows that the Branch movement has passed a formative period and has settled down to a working basis.

It is noticeable from the table that the meetings have been held with regularity and that the attendance has been large. The average attendance in percentage of the available membership will compare very favorably with that of the New York meetings. It is also noticeable that more attention has been given to the presentation of original matter and less to the consideration of the New York papers than in former years.

The committee has been much impressed with the activity of the University Branches and Student Meetings. Their work differs essentially from that of the regular Braches in that it is largely educational. Their function is to assist in the development of younger men and to bring them into touch with the Institute at the threshold of their careers. How well they are doing this work and the importance of encouraging it can be estimated from the number of young men who are being reached in this way. The statistics speak for themselves.

Cornell shows an average attendance at its meetings of 130 with a maximum of 225; Purdue, an average of 100, a maximum of 265; Wisconsin, average 60, maximum 175.

In fact, virtually all of the University Branches show that the Students of the Institute are taking an active interest in the work. The following quotation from a letter received from Professor Esty of Lehigh University expresses very well the general situation at these organizations:

> Our year just closing has been the most successful in our history. I regard the social feature of our monthly meetings as a most important element in stimulating interest. We are training our students to become active and useful future members of the Institute. Local organizations of this kind certainly pay enormous dividends on the investment.

Letters were sent to the Branches asking for an expression of opinion as to the year's work and as to future prospects. In answer to the question; "Has the current year been successful and shown a healthful increase in interest and activity?" the reply has almost invariably been an emphatic "Yes." Judging from the reasons given in these replies, this success has been due to the following causes and in about the order of importance as stated:

1. To an enthusiastic and hard working set of men at the head of the Branch.
2. To the consideration of original papers of local interest instead of a rehash of the New York papers.
3. To the increased recognition of the Branches by the Institute.
4. To the development of a certain amount of social features.

The replies to the question: "What is most needed to further the interest of the Local Organizations?" have shown a remarkable unanimity. Some say that a larger appropriation from the Institute funds is required to permit an expansion of the work, the hiring of better meeting quarters, and an increase of social features. Practically all are united in saying that there is needed a greater coöperation between the Branches and the Institute. All believe that occasional visits to the Branches by officers and prominent members of the Institute would increase the enthusiasm of the Branches themselves and would strengthen the bond between them and the Institute.

The above digest of the replies of

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the Branches to these two important questions which are in effect: "How has success been attained in the past?" and "How can it be continued and increased in the future?" would seem to indicate that there is necessarily a development along two lines:

1. In order that the work done by the Branches can be of any value at all, either to themselves or to the Institute, they must be encouraged to develop as strong local societies.

2. In order that these local centers may be part and parcel of the Institute and may add strength rather than weakness to it, there must at the same time be developed a spirit of unity and coöperation between these scattered and distant organizations and the main body of the Institute.

The first line of development is largely in the hands of the Branches themselves; they must justify their existence by their results. The clauses in reference to the local organizations in the revised Constitution are very broad in their features and will permit any Branch to work along the lines best suited to its locality. The following would seem to be some of the conditions bearing on the possibility of local success:

There should first of all be a large enough membership in the territory properly belonging to a Branch to enable the work to be carried on without its being necessary to depend on two or three enthusiasts. The present By-laws require ten Members and Associates as the minimum number for the formation of a Branch. This number we believe to be too low and would recommend that it be increased to at least twenty-five. This, of course, does not apply to University Branches or Student Meetings. Their formation should, in the future, as heretofore, be encouraged in any institution of recognized standing.

Branches should take their work seriously, and should organize with officers and committees chosen with that end in view. It is particularly important that officers for the ensuing year should be selected before the summer vacation, so that they may be ready to take hold vigorously with the opening of the work in the autumn.

As definite a program as possible should be laid out early in the year. It may be more or less tentative and changed as the year progresses, but a plan to work by will both lessen the burden of the work and insure more interesting meetings.

Younger men should be encouraged to take a prominent part, so that they can be fitted to become officers of the Branches, bringing in new ideas and relieving those who have been carrying on the work.

The consideration of original papers will be found necessary in order to keep up the interest.

Social features and visits of prominent engineers will also add very much to the interest of the work, but are largely a matter of expense.

The expense question is always a difficult one to handle. The funds of the Institute are limited, and on account of the number of Branches it is difficult to appropriate for each Branch a sum sufficiently large to satisfy all of its requirements. The necessary expenses for engineering meetings, such as the rent for a hall, the cost of sending out notices, and of a stenographer at the meetings, should be met from the Institute funds. To a certain extent we believe it would be wise for the Institute to bear the expense in connection with visiting engineers. The expense of social features should be paid out of local funds and not charged against the Institute.

In order to strengthen the bond of unity and coöperation between the Branches and the Institute, there should certainly be continued the liberal attitude which has been shown by the administration this year. The publication of meritorious Branch papers in the PROCEEDINGS will help along these lines. The larger publicity to Branch

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affairs which has been given in this year's PROCEEDINGS has undoubtedly been of great assistance in strengthening the Branch work. The Branches can be further made to feel that they are an integral part of the Institute, if they are asked to assist, as far as possible, in the work of the Institute. They should be represented on committees, and with due regard to the possibility of assembling a working quorum they should be represented on the Board of Directors. Personal visits to the Branches on the part of officers and prominent members would be most helpful in bringing about this feeling of coöperation.

In conclusion we would bring to the attention of the Institute at large, and especially to any members who may have any doubts as to the wisdom of encouraging the Branch work, the fact that this work can be no longer considered as in an experimental or temporary stage. The wisdom of starting the Branch movement is no longer a proper question for debate: the Branches are here with an immense possibility for useful work. It is not conceivable that this work started in the broadest spirit of the greatest good to the entire membership of the Institute can be allowed to languish through a lack of appreciation of its possibilities or through a lack of coöperation either on the part of the Branches themselves or on the part of the main body of the Institute.

For the Committee on Local Organizations.

PAUL SPENCER, *Chairman.*

Sections and University Branches

TOLEDO SECTION

The regular monthly meeting of Toledo Section, was held August 2, 1907, at the Boody House. The secretary, Geo. E. Kirk, presided owing to absence of the chairman.

After transacting routine business, Dr. Lee DeForest was introduced. The address given by Dr. DeForest was most clear and entertaining, accompanied by sketches on the blackboard. The sensitiveness of the arc to electric waves, and the adaptation of this scheme to space or wireless signaling was outlined, followed by references to coherer, polariphone, and other instruments for similar purposes, including the audion.

The general circuits were explained. and the methods of tuning, which may be such as to permit quite a number of stations in overlapping fields without interference. The advantages of the wireless telephone over the wireless telegraph, were compared as the wire telephone to that of wire telegraph.

On invitation of Dr. DeForest, after the meeting the members were given an opportunity to visit the wireless telephone station in the Ohio Building, Toledo, where receiving and transmitting was conducted by those present with a station some two blocks distant in the Nicholas Building. Besides conversing, a phonograph rendered several selections from the Nicholas station, showing the transmission to be most accurate. These stations are to be used in developing the wireless telephone on the great lakes.

The Section adjourned to meet the first Friday in September.

Associates Elected

At a regular meeting of the Board of Directors held in the Engineers' Building, 33 West Thirty-ninth street, New York, Friday, August 30, 1907, at 3:30 p.m., the following 55 Associates were elected:

ADAMS, ARTHUR L., Malden Electric Co.; res., 70 Linden Ave., Malden, Mass.

BARFOED, SVEND, Draftsman, F. G. Baum & Co., 1406 Chronicle Bldg., San Francisco, Cal.

BIEGLER, PHILIP SHERIDAN, Instructor in Electrical Engineering, State University of Iowa, Iowa City, Iowa.

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CALKINS, GEORGE HERBERT, Manager, General Electric Co., 681 Ellicott Square, Buffalo, N. Y.

CLIFFORD, CHARLES SHED, Agent, General Electric Co., 681 Ellicott Square; res., 331 Franklin St., Buffalo, N. Y.

COX HERBERT FREDERICK, Mechanical Electrical Engineer, U. S. Government, Ft. Bayard, New Mexico.

CRABBS, LOUIS CLAIR, Salesman, F. Bissell Co.; res., 1631 Peoria St., Toledo, O.

DAVENPORT, FREDERICK ST. JOHN, Electrician, Atlanta Telephone and Telegraph Co.; res. 75 Edgewood Ave., Atlanta, Ga.

DAVIS, JOSEPH LECONTE, Designing Engineer, Westinghouse Electric and Mfg. Co.; res., 4924 Centre Ave., Pittsburg, Pa.

ELKEN, ARTHUR, Electrician, Mexican Light and Power Co., Mexico D. F., Mex.

EMERY, WILLIAM LORENZO, Foreman, Meter Department, Utah Light and Railway Co., 830 Emeril Ave., Salt Lake City, Utah.

FAIRLEY, GEORGE EDWARD ALBERT, Penniman and Fairley, 416 Marine Bank Bldg., Baltimore, Md.

FLOYD, WILLIAM HARRIS, 3d, Assistant in Standard & Research Laboratory, Telluride Power Co., Provo, Utah.

FORAKER, BURCH, Assistant to Superintendent of Construction, New York Telephone Co.; res., 122 W. 94th St., New York City.

FROEHLICH, FRED HERMAN, Consulting Engineer, 944 Ohio Bldg.; res., 12 W. Delaware Ave., Toledo, O.

GOODWIN, VICTOR EARL, Electrician, General Electric Co., Schenectady, N. Y.

GRANT, RUDOLPH REDELL, Chief Inspector, Electrical Inspection De-part ment, City of Norfolk, Norfolk, Va.

HALL, FREDERIC DAVIS, Chief Electrician, Boston and Main Railroad, 152 Causeway St., Boston; res., Somerville, Mass.

HALL, HARRY SINCLAIR, Station Foreman, Mexican Light and Power Co., Necaxa, Puebla, Mexico.

HARRINGTON, ALLAN COLLINS, Resident Engineer, Buffalo Lockport and Rochester Railway Co., Albion, N. Y.

HERSEY, FRED WALTER, Chief Draftsman, Brush Electrical Engineering Co., 6 Charnwood Road, Loughborough, England.

HUTCHINSON, ADELBERT ANSON, Engineer of Construction, Potomac Electric Power Co.; res., 1975 Biltmore St. N. W., Washington, D. C.

HUTTON, WILLIS A., Sales Engineer, General Electric Co.; res., 118 E. 23d St., Erie, Pa.

JONES, ARTHUR JAMES, Asst. to Superintendent, Niagara Falls Power Co.; res., 3 Lochiel Apartment, Niagara Falls, N. Y.

KITT, FREDERICK THEODORE, Foreman of Sub-station, Sacramento Electric Gas and Railway Co., 431 21st St., Sacramento, Cal.

LEUREY, LOUIS FRANCIS, Electrical Engineer, Sanderson and Porter, 4149 Canal St., New Orleans, La.

LLOYD, MILO CLINTON, Electrical Machinery Salesman, F. Bissell Co.; res., 419 14th St., Toledo, O.

LOIZEAUX, ALFRED SAMUEL, First Assistant Electrical Engineer, New York Edison Co., 55 Duane St., New York City.

MCBRIDE, LEWIS MITCHELL, Electrical Engineer and Superintendent, Carstarphen Electric Co., 20 W. Colfax Ave., Denver, Colo.

MCELWEE, GEORGE JOHNSTONE, Substation and Test Room Electrician, Municipal Council's Electric Supply Department; res., 73 Cameron St., Launceston, Tasmania.

MCGEACHIN, WILLIAM RANKIN, Engineer, Manila Electric Railroad and Light Co., Manila, P. I.

MILLARD, ALFRED LEVI, Salesman, Westinghouse Electric and Mfg. Co., 171 LaSalle St., Chicago; res., Park Ridge, Ill.

MILLS, FREDERICK SHANNON, Traveling Representative, Westinghouse Electric and Mfg. Co., 1230 7th Ave., San Francisco, Cal.

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MONYNIHAN, ROBERT EDMUND, Assistant Engineer, Power House Section, British Westinghouse Electric and Mfg. Co., Westinghouse Works, Trafford Park, Manchester, England.

NOYES, JOHN DRAPER, Engineer, Erection Department, Westinghouse Electric and Mfg. Co., 60 Alexandrine St., East, Detroit, Mich.

PARRINGTON, CHARLES LASCELLES, Manager, Steuart & Fenn, Ltd., Dunedin, New Zealand.

PETERS, ALFRED STANLEY, Engineer, Rocky Mountain Bell Telephone Co., Salt Lake City, Utah.

PETTIT, IRVING C., Instructor, Experimental Electrical Engineering, Cornell University; res., 804 E. Seneca St., Ithaca, N. Y.

RAINEY, LOUIS THOMAS, Manager, Power and Mining Department, General Electric Co., Cincinnati, O.

RAUSCHENBERG, OSCAR CALDWELL, Engineers' Inspector, Southern Bell Telephone and Telegraph Co., 133 So. Moreland Ave., Atlanta, Ga.

RHETT, EDMUND MOORE, Electrical Engineer, Central of Georgia Railway Co., Savannah, Ga.

SAKUMA, CHARLES GONGIRO, Chief Engineer, Mino Electric Railway and Fuji Hydraulic Power Plant, No 12 Ichibanchi, Naitocho, Yotsuyaku, Tokyo, Japan.

SATTERLEE, JOHN PAUL, Electrical Engineer and Superintendent of Construction, J. G. White and Co., Gales Ferry, Conn.

SMALL, FRED FULTON, Chief Draftsman, Pacific Electric and Los Angeles Interurban Railway Co., Los Angeles, Cal.

SOMMER, KARL ERNEST, District Engineer, Westinghouse Electric and Mfg. Co.; res., 1630 N. Calvert St., Baltimore, Md

SOTHMAN, PETER WILLIAM, Chief Engineer, Hydro Electric Power Commission of Ontario, Continental Life Bldg., Toronto, Ont.

STULL, EMMETT W., Engineer, Railway way Department, Bullock Electric Mfg. Co., Cincinnati, O.

SUMMERHAYES, HENRY ROSWELL, Assistant Engineer, Foreign Department General Electric Co., Schenectady, N. Y.

TIPLADY, JOHN T., Foreman, Westinghouse Electric and Mfg. Co., Pittsburg; res., 396 Center St., Wilkinsburg, Pa.

VAN DEMARK, HOWARD MONTAGUE, Telephone Engineer, Western Electric Co., New York; res., 126 Columbia Heights, Brooklyn, N. Y.

WARD, BALDWIN D., Electrical Foreman, Fort Worth Light and Power Co., 1001 Rusk St., Fort Worth, Tex.

WAY, HOLROYD FITZWILLIAM, 2d Engineer, Dunedin City Corporation, Electric Power Department, Waipori Falls, Dunedin, Otago, N. Z.

WESLEY, JOSEPH JOHN, Member of Firm, Metropolitan Switchboard Co., 540 W. 22d St., New York City.

WESTMAN, ADOLF, Electrical Draftsman, General Electric Co.; res., 514 Summit Ave., Schenectady, N. Y.

WICKENDEN, WILLIAM ELGIN, Instructor, Electrical Engineering, University of Wisconsin, Madison, Wis.

The following Associate was transferred to the grade of Member:

ROBERT JULIAN SCOTT, Professor of Engineering and Electricity, New Zealand University, Christchurch, N. Z.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the Secretary before September 27, 1907.

6641 J. C. Elberson, Philadelphia, Pa.
6642 W. G. Rogers, Philadelphia, Pa.
6643 T. R. Taltavall, New York City.
6644 John Gilmartin, Toledo, Ohio.
6645 J. E. Kearns, Schenectady, N. Y.
6646 W. P. Phillips, Bridgeport, Conn.

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6647 G. R. Houston, Birmingham, Ala.
6648 G. B. Roberts, St. Josephs, Mo.
6649 J. F. Morgan, Hazelton, Pa.
6650 A. F. Harger, Hazelton, Pa.
6551 H. H. Heaton, Hauser Lake, Mont
6652 C. W. Sirch, Los Angeles Cal.
6653 Jerome Carty, New York City.
6654 T. W. Gardner, Nashville, Tenn.
6655 E. T. Mahood, St. Louis, Mo.
6656 F. R. Phillips, Mansfield, Ohio.
6657 Cornelius Thompson, Toledo, O.
6658 A. B. Fuller, Brooklyn, N. Y.
6659 C. N. Thomas, Providence, R. I.
6660 R. N. Thomas, Minoa, N. Y.
6661 J. R. Wilson, Havana, Cuba.
6662 J. R. Burriss, Anderson, S. C.
6663 G. H. Cadwell, Mexico City, Mex.
6664 Alvin Fox, Chicago, Ill.
6665 A. B. Mann, Cincinnati, O.
6666 L. L. Smith, Madison, Wis.
6667 A. S. Andrews, Bangalore, S. India
6668 J. G. DeRemer, Berkeley, Cal.
6669 G. R. Jenkins, Mexico City, Mex.
6670 J. R. McFarlin, Keokuk, Iowa.
6671 H. G. Fenton, Mexico City, Mex.
6672 G. L. Preacher, Augusta, Ga.
6673 W. T. Peck, Schenectady, N. Y.
6674 P. H. Burns, Nassau, Bahamas.
6675 G. A. Joffe, E. Pittsburg, Pa.
6676 W. H. Harriss, Atlanta, Ga .
6677 M. J. Laurencena, Buenos Aires.
6678 N. C. Mills, Schenectady, N. Y.
6679 H. J. S. Heather, Johannesburg.
6680 A. R. Clark, Birmingham, Ala.
6681 G. H. Bolus, Mansfield, Ohio.
6682 J. R. W. Gardam, Sidney, N. S. W.
6683 A. E. Lundell, Chicago, Ill.

Total, 43.

Applications for Transfer

Recommended for transfer by the Board of Examiners, August 16, 1907.

Any objection to these transfers should be filed at once with the Secretary.

EDSON OLIVER SESSIONS, western sales engineer, Stanley-G. I. Electric Mfg. Co., Chicago, Ill.

FRANK RICHARDS FORD, consulting engineer, 24 Broad Street, New York City.

CHARLES HOLLAND MORITZ, General superintendent Niagara Works, Aluminum Co. of America, Niagara Falls, N. Y.

REUBEN IRVING WRIGHT, engineer, The Electric Controller & Supply Co., Cleveland, Ohio.

DAVID HALL, assistant chief engineer, The Bullock Electric Mfg. Co., 4816 Ash St., Station H., Cincinnati, Ohio.

Personal

MR. H. MCCULLOUGH has accepted a position as electrical engineer for the Pittsburgh and Montana Copper Company, of Butte, Montana.

MR. W. T. TAYLOR has left Mexico on a short business trip to England, and during his absence Mr. George Greenwood will act as his substitute.

MR. GEO. W. BROOME has left the main works of the General Electric Company, to do installation work on the road from the Philadelphia office.

MR. HARRY J. WOLF, lately mining engineer to Camp Bird, Ltd., has accepted the position of superintendent and engineer of the Stanley Mines Company, Idaho Springs, Colorado.

MR. J. B. KENNEDY, having left the Cutler-Hammer Mfg. Company, is now engaged in the chief engineer's office of the Department of Water Supply, Gas and Electricity, New York City.

MR. MAX FREIMARK has been for some time absent in Germany, where he found opportunity for a study of the telephone art there, especially in Bavaria. He returned to this country July 24.

MR. H. S. RUSH has left the testing department of the General Electric Company, Schenectady, N. Y., and is now in the inspection department of the North Shore Electric Company, at Evanston, Ill.

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MR. H. A. STANLEY, formerly construction foreman with the Stanley-G. I. Electric Mfg. Company of Pittsfield, Mass., is now engaged in construction work with the General Electric Company, Schenectady, N. Y.

MR. B. H. BENDHEIM is at present associated with F. E. Newbery and Company, electrical engineers and contractors of St. Louis, with the expectation of being placed in charge of one of their western offices in the near future.

MR. J. FRANKLIN SHOEMAKER has given up his position as electrical engineer with the Gisholt Machine Company, of Madison, Wisconsin, to accept that of master mechanic with the Warren Springer Company, of Chicago, Ill.

MR. P. L. MCCAIN, of the General Electric Company, has been transferred from its testing department at Schenectady, to the position of erecting engineer, with headquarters at Philadelphia. He is at present located in North Carolina.

MR. BRODER G. SON BERGMAN now has a position as electrical engineer with Elektriska Prufungs Anstalten, Stockholm, electrical consulting, engineering, and testing firm. His specialty in that position is electrical railroading.

MR. H. F. DARBY, JR., formerly in charge of the Cutter Company's Pittsburg district, has recently opened an office at 1613 Chemical building, St. Louis, Mo., to take care of the sales of I-T-E circuit breakers in the south and southwest.

MR. ALLEN G. JONES has been transferred from the Lynn works of the General Electric Company to the commercial transformer department at Schenectady, in view of being sent out on similar work to one of the district offices of the company.

MR. LEE H. KIDDER has left the construction department of the Westinghouse Electric and Manufacturing Co., and is now employed by the Pittsburgh and Butler Street Railway, and the Butler Passenger Railway companies, at Butler, Penn.

MR. C. F. ADAMS, after several years service with the Stanley-G. I. Electric Mfg. Company of Pittsfield, as superintendent of construction, is now located in San Francisco, with the engineering department of the California Gas and Electric Corporation.

MR. W. M. N. EGLINTON has been transferred from the forces of Messrs. W. R. Grace and Co., to take charge as chief constructing engineer and administrator of the Compania Electrica de Concepcion, with headquarters at Concepcion, Chili, South America.

MR. JIN TACHIHARA has been transferred from Tokyo to Kobe, Japan, to take charge of the electrical department of the Mitsu Bishi dockyard and engine works there, which has been lately enlarged to meet the demands of the company as well as those of the general public.

MR. F. A. MCCARTY, formerly of the Westinghouse Construction Department, has resigned from Noyes Bros., and has started in business on his own account at 31 Queen Street, Melbourne, Australia. Mr. McCarty is representing a number of American, English, and Continental firms.

MR. C. W. HUMPHREY, formerly consulting engineer for the Denver Gas and Electric Company, and subsequently consulting engineer and manager for the Northern Colorado Power Company, has opened an office as consulting and designing engineer, in The Rookery, Chicago.

MR. D. MARTIGNONE, electrical superintendent for the East St. Louis and

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Suburban Railway, of East St. Louis, Illinois, has resigned his position in the above company, to resume his connection with the construction department of the General Electric Company, at Schenectady, N. Y.

Mr. E. M. Tingley is at present in the country for the purpose of improving his health, having an indefinite leave of absence from the engineering department of the Westinghouse Electric and Mfg. Company, of Pittsburgh, Pa., with which he has been connected for about fourteen years.

Mr. L. H. Haynes, who has been with Westinghouse, Church, Kerr and Company on the electrification of the Rochester division of the Erie Railroad, from the commencement to the completion of this work, has left that company. His present address is 3214 Vernon Ave., Chicago, Ill.

Mr. Theodore I. Jones has lately been appointed sales department manager of the United Electric Light and Power Company of New York City, to take full charge of that branch of the business, including all contracts covering electric light, power, heat, and sign work, and all advertising.

Mr. Chris J. Walbran, Jr., formerly in the New York offices of F. A. C. Perrine, consulting engineer, and at present in charge of the Summit County Power Company development at Dillon, Colo., has been appointed manager of a new branch office in Denver, Colo., at 252 the Equitable Building.

Mr. Milton P. Gallup has located in Providence, R. I., having returned to the East from San Francisco, where he had been connected with the Pacific Telephone and Telegraph Company, in the engineering department. He is now associated with the engineering department of the Providence Telephone Company.

Mr. E. J. Cook has been appointed general manager of the Rochester Railway Company, Rochester, N. Y. Mr. Cook is a graduate of Stevens Institute of Technology, and has been chief engineer of the Consolidated Street Railway properties in Cleveland, Ohio, since 1903. He is also a member of the American Society of Mechanical Engineers.

Mr. O. H. Ensign, consulting engineer for the U. S. Reclamation Service, with working title of chief electrician and mechanical engineer, at Los Angeles, California, has lately accepted the offer of professorship of electrical engineering at the Wisconsin State University, Madison, while still retaining his position with the reclamation service.

Mr. John Coffee Hays, having resigned his position as assistant engineer with L. B. Stillwell, goes to California to accept the position of president and consulting electrical engineer of the Mt. Whitney Power Company, and president of the Visalia Electric Railroad. Mr. Hays will also do general consulting work, in making reports and examinations of water power and railroad plants.

Mr. C. J. Spencer, recently technical writer in the publication department of the Westinghouse Electric and Mfg. Co., at Pittsburg, is now editor of the *Electrical Age*, 45 East 42d Street, New York City, beginning with the August number. This appointment is in line with the policy of the *Electrical Age* Company in making the predominant feature of the paper engineering articles by engineers.

Mr. E. W. McClintic, who was formerly with the Lackawanna Light Company, of Scranton, Pa., and who at the time the companies of Scranton were absorbed by the American Gas and Electric Company, under the name of Scranton Electric Company, was transferred to that office for a while, has now been transferred to the main office of the

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American Gas and Electric Company, in Philadelphia.

Mr. Horace B. Gale, who has been identified with the Submarine Signal Company of Boston for several years, has been appointed chief engineer for the Simplex Electric Heating Company, of Cambridge. In making this change, Mr. Gale returns to the position that he held ten years ago in the days of the small beginning of the electric heating business, which is now in a rapidly growing condition.

Mr. Oddgeir Stephenson has resigned the position he has held for three years with the Wagner Electric Mfg. Company, to take up a year's special work in electrical engineering in the University of Illinois, where he has accepted an appointment as assistant in electrical engineering. Mr. Stephenson expects to be identified to a considerable degree with the Institute work at the local Section.

Mr. Guy K. Mitchell, who for the past five years has been connected with the distribution department of the Consolidated Gas, Electric Light, and Power Company, of Baltimore, has resigned, and has associated himself with the Crook-Horner Company of Baltimore, as superintendent, engineer of the electrical construction department, and is now engaged in installing motor drives for industrial plants, also underground cable work.

Mr. James B. Scott, consulting engineer, and a member of the American Society of Mechanical Engineers, has removed to his new offices, 203-206 Maryland Savings Bank Building, Baltimore, where he is associated with Mr Daniel B. Banks, for many years chief engineer United Railways and Electric Company of Baltimore, and with Mr F. W. Keyser, C. E., University of Christiana; Doctor of Technology, University of Berlin; Member Norwegian Society Engineers and Architects; specialist in the design of reinforced concrete structures.

Messrs. T. L. Miller and Wilson, consulting engineers, of 18 Westminster Chambers, 1 Crosshall Street, Liverpool, and 19 Brazenose Street, Manchester, have taken into partnership Mr. Henry Villiers Pegg, A. M. Inst. C. E., and have opened an office at 47-48 Scottish Temperance Insurance Buildings, Donegal Square, Belfast, and will in future practise under the style of T. L. Miller, Wilson, and Pegg. The partnership existing between Messrs. Thos. L. Miller and Adrian Collins, practising in London at 61 Old Broad Street, under the style of Miller and Collins, has been terminated by mutual consent, as from the 31st July, 1907.

Books Received

The following volumes have been received from the McGraw Publishing Company and placed in the Library of the Institute:

American Telephone Practice A comprehensive treatise, including descriptions of apparatus, line construction, exchange operation, etc. By Kempster B. Miller. Fourth edition entirely rewritten and greatly extended. 904 pages, 643 illustrations. New York, McGraw Publishing Co. Price, $4 net.

Chapter I.—History and Principles of the Magneto Telephone. II.—History and Principles of the Variable Resistance Transmitter. III.—Electromagnetic and Electrostatic Induction. IV.—The Telephone Receiver. V.—The Carbon Transmitter. VI.—Induction. Coils for Local Battery Telephones. VII.—Primary Batteries. VIII.—Magneto Calling Apparatus. IX.—Local Battery Sub-station Equipments. X.—Telephone Lines. XI.—The Telephone Exchange in General. XII.—The Magneto Switchboard for Small Exchanges. XIII.—The Theory of the Multiple Switchboard. XIV.—The Magneto Mul-

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tiple Switchboard. XV.—Transfer Systems. XVI.—Systems of Transmission in Common Battery Exchanges. XVII. Signaling in Common Battery Systems. XVIII.—Common Battery Switchboards in Small Exchanges. XIX.—Common Battery Sub-station Equipment. XX.—The Common Battery Multiple Switchboard. XXI.—Trunking System between Common Battery Offices. XXII.—The Divided Multiple System. XXIII.—Private Branch Exchange Service. XXIV.—Party Line Systems. XXV.—Measured Service. XXVI.—Toll Switchboard Systems. XXVII.—Details of Multiple Switchboard Apparatus. XXVIII.—Power Plants in Common Battery Systems. XXIX.—Storage Batteries. XXX.—Protective Devices. XXXI.—Distributing Frames. XXXII.—Chief Operator's and Monitor's Equipments. XXXIII.—Wire Chief's Equipment. XXXIV.—The Layout and Wiring of Central Office Equipments. XXXV.—Automatic Switchboard Systems. XXXVI. — Intercommunicating Systems. XXXVII.—The Telephone Relay or Repeater. XXXVIII.—Wire for Telephone Use. XXXIX.—Pole-Line Construction. XL.—Aerial Cable Construction. XLI.—Underground Cable Construction. XLII.—Testing.

KEYS FOR THE PRACTICAL ELECTRICAL WORKER. Electric light, power, street railway, telephone and the telegraph explained and illustrated by drawings and diagrams of connections from the latest practice. By F. J. Robinson. Cloth, 193 pages, folding plates. Price, $2 net.

CONTENTS.—Connections for A. C. Machines, A. C. Switchboards, A. C. Motors, Recording Wattmeters, A. C. Series Arc Lighting Systems, and Transformers. Rules and Tables. General Wiring Formula for A. C. Practical Electrical Units. Different Systems of Wiring for Light, Power, Bells, etc. Connections for D. C. Generators and Motors, D. C. Switchboards, D. C. Series Arc Lighting Systems, D. C. Rheostats and Controllers, Lightning Arresters. Connections of the Telephone. The Morse Code and Alphabet. Connections for the Various Telegraph Systems.

TELEPHONY. Relates especially to the engineering design of telephone plants, with reference to the economic features which lead to the installation of the best plant for the least money. By A. V. Abbott, C.E. Price of the entire set, 6 vols., $6 net. Sold separately, $1.50 each, net. New York, McGraw Publishing Company.

Vol. V. The Sub-station. Cloth, 465 pages, 310 illustrations. Price, $1.50 net.

Chapter I.—Introduction. II.—The Receiver. III.—Telephone Transmitters. IV.—Induction Coils and Substation Circuits. V.—Transmission and Current Supply. VI.—Signaling Apparatus. VII.—Protection. VIII.—Party Lines. IX.—Sub-station Assemblage. X.—Costs of Installation and Operation.

Vol. VI. Switchboards and the Central Office. Cloth, 271 pages, 169 illustrations. Price, $1.50 net.

Chapter I.—Introduction. II.—Distributing Boards. III.—Circuits and Apparatus for Small Switchboards. IV. Transfer Systems and the Multiple Boards. V.—Common Battery Circuits. VI.—Toll Line Circuits. VII.—The Power Plant. VIII.—Traffic.

STANDARD TELEPHONE WIRING. Simple directions for connection to the central office wires the common battery magneto-telephone as now installed by leading telephone companies in this country. By J. F. Fairman. Flexible leather. 91 pages 74 illustrations. New York, McGraw Publishing Co. Price, $1 net

CONTENTS.—Introduction. I.—Telephone Apparatus. II.—Installation. III.—Common-battery Systems. IV.—Magnet Systems. V.—Troubles. VI.—Fire Underwriters' Rules.

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Boston............Feb. 13, '03	H. E. Clifford.	C. H. Porter.	3d Wednesday
Chicago..................1893	P. B. Woodworth.	H. R. King.	1st Tuesday after N. Y. meeting.
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Columbus.........Dec. 20, '03	R. J. Feather.	H. L. Backman.	1st Monday.
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Minnesota..........Apr. 7, '02	H. J. Gille.	Barry Dibble.	2d Monday after N. Y. meeting.
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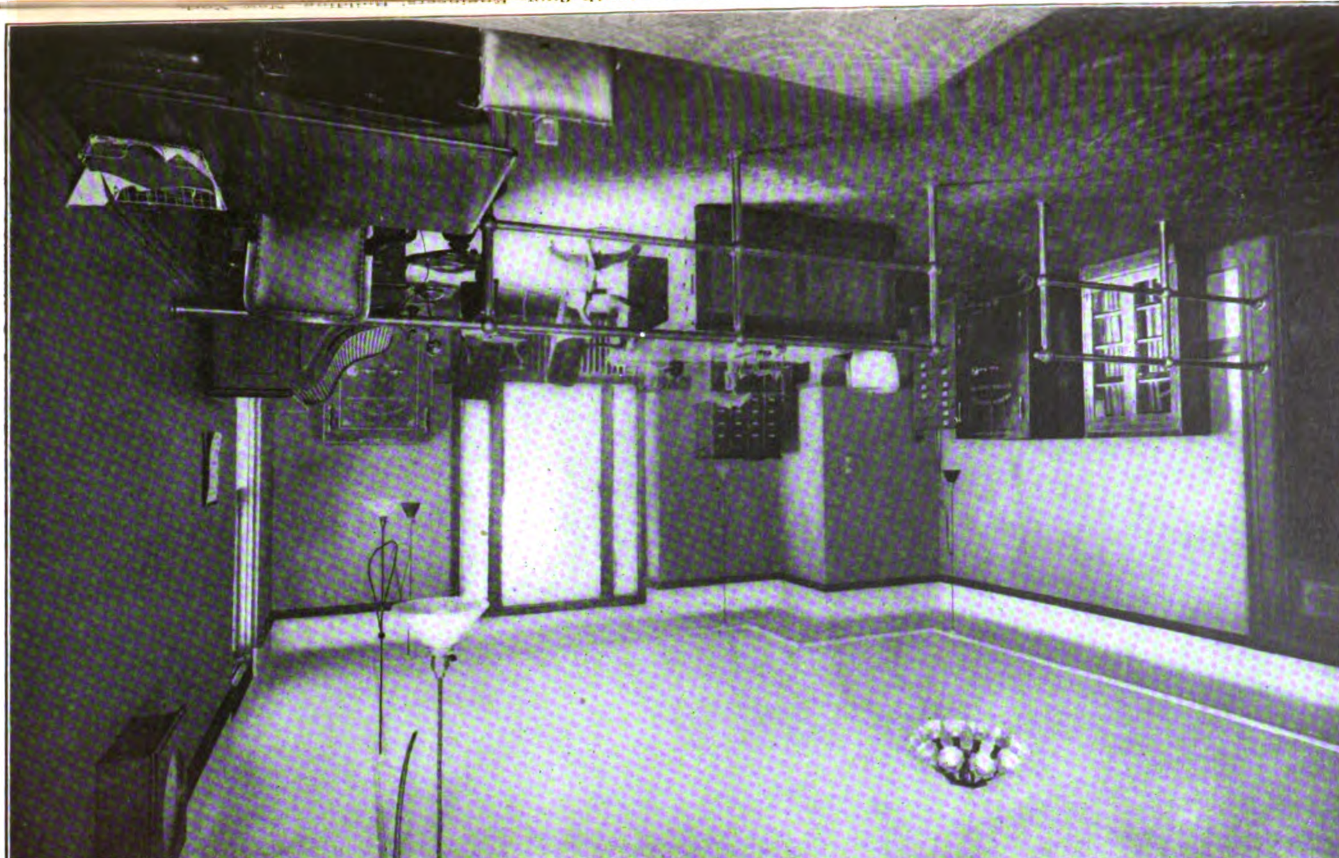

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American Institute

OF

Electrical Engineers.

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Meetings

THE value of a technical society to its members is so largely dependent upon meetings, that their character is a matter of supreme importance. There should be a continual effort toward improvement, not only in the grade of papers, but in the technical value of the discussions, and the general conduct of meetings. The experience of various Sections should be drawn upon for useful hints. Lantern slides have proved to be very popular, but facilities for their introduction are not always available. Whenever used, the speaker should have a preliminary rehearsal with the operator, in order that they may work in harmony. Unless absolutely necessary for a proper understanding of a paper, it is preferable to group the slides at the close, accompanied by very brief informal descriptions. Local meetings in various parts of the country now offer an opportunity for a continually increasing proportion of the membership to take a more active part in the work of the Institute. Just prior to the Niagara Falls convention, the Local Organizations Committee was authorized by the Board of Directors to call attention to the privilege of each chairman to represent his Section on that occasion. The result was very gratifying, and including these delegates, the following states, districts, provinces and countries were represented: New York, Pennsylvania, New Jersey, Massachusetts, Washington, Maryland, Minnesota, Nebraska, North Carolina, Tennessee, Montana, Indiana, Illinois, Ohio, Iowa, Missouri, Wisconsin, Connecticut, West Virginia, Michigan, District of Columbia, Ontario, Quebec, Manitoba, England, and Germany. Experience indicates that future conventions will gradually become more national in character, and that an effort should be made to obtain papers of world-wide interest in order that the discussions may be enriched by the experience of engineers working under varying conditions.

Back to the Farm

THERE has been widespread recognition of the drift of young men from agriculture to the more attractive industrial field. Financial betterment has without doubt been the chief incentive, but there is a fascination in electrical work which has had an important bearing upon the movement. Engineers who have accumulated sufficient wealth to enable them to purchase and operate a large farm, have in some instances found rest and recreation in the actual practice of agriculture. Conditions are changing, however, and it appears possible that in the future small farms will be merged into such large tracts that their most efficient and economical op-

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eration will demand electrical distribution. The difficulty of obtaining farm hands who are able and willing to milk, has reached a point where dairies are being abandoned, and the land used for other purposes. For at least fifty years inventors have toyed with the problem of a successful milking machine. The press agent of the New York Electrical show announced such an exhibit, prefaced by the statement that thousands of people in New York City had never seen a cow, and thousands more had never seen a cow " get milked ". But electricity is by no means confined to this restricted field of farm work. A plant in a small town in Ohio furnishes current to milk cows, thresh grain, cut fodder, fill silos, husk corn, grind feed, pump water, saw wood, separate cream, churn butter, wash clothes, light barns and houses. Telephone and signal bells have become ordinary conveniences, the use of motors for field work will certainly increase, and in locations where water power is available, there would seem to be ample opportunity for the young electrical engineer to utilize his genius in adding to the growing prosperity of the scientific farm.

Standardization Rules

THE revised rules recommended by the Standards Committee and approved by the Board of Directors were printed in the July issue of the PROCEEDINGS. It is well known that these rules are the outgrowth of the original code promulgated in 1899. They represent an immense amount of conscientious work by the committee, and numerous suggestions have been considered at its various sessions. Experience has shown that these rules have been of great service in the electrical field, although progress has been so rapid that it is becoming an exceedingly difficult matter to keep them up to date, and at the same time meet all requirements of the profession. Members should use every effort to call attention to the importance of substituting the new rules for those which are now obsolete. In addition to the usual pamphlet edition, copies are now available bound in substantial cloth covers, which will be more convenient for desk use. Further details are given in the advertising section of this issue.

Unauthorized Publication

PAPERS read at meetings of Sections are the property of the Institute, and consequently the Institute must maintain the privilege of prior and exclusive publication. If not acceptable for this purpose, the author may then arrange for printing elsewhere. In two recent instances where papers of this character have been accepted for printing in the PROCEEDINGS, they have appeared in the technical press, which accordingly debars subsequent publication by the Institute. Officers of Sections are expected to exercise their judgment as to the apparent suitability of local papers for publication by the Institute, and forward copies to the Secretary for approval by the Meetings and Papers Committee as provided in the By-laws.

THE danger of overhead wires has in the past received considerable attention from the press, and the falling of poles, weakened by decay, has always been recognized as a continual menace. An agitation is now being made in the interest of automobilists for the removal of poles from the highway, on account of the many serious accidents which have been caused by colliding with them. The natural outgrowth of this movement would seem to be to include also such obstacles to wild motoring, as horses, wagons, shade trees, rocks, hitching posts, and possibly curbstones. The old Amherst and Belchertown Railroad was practically immune from collisions, by reason of its equipment being limited to one locomotive. If there were but one automobile confined in a garage, motoring accidents would be reduced to a minimum.

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Gas-Power Central Station of the Duquesne Light Co., Pittsburg, Pa.*

NOTES ON EQUIPMENT AND OPERATION.

Although the territory now supplied by the Duquesne Light Company was already covered by the distribution system of another company, there seemed to be room for further business for a central station securing the advantages of more uniform regulation and distributing directly from the center of gravity of its load, thus obviating the first cost, the maintenance, and the losses of long transmission lines. Work was begun on June 28, 1906, and by October 5, the power station and distribution system were far enough completed to start regular 24-hour service. During the following six months the service increased so rapidly that the station is now heavily loaded and running on an excellent load-factor. The service consists of residential and commercial lighting and power, and these merge into a load having an exceptionally long hour evening peak and a fairly even day load. The 60-cycle generators are wound three phase, star connected, and the distribution is partly underground and partly overhead to standard 2200-volt transformers, which in turn are connected to 110/220-volt secondaries.

The power station.—In the choice of site and equipment, several factors had to be carefully considered.

a. Proximity to electrical "center of gravity."

b. Coal supply for steam or gas plant.

c. Natural gas supply for gas plant.

d. Water supply for condensing or cooling purposes.

The power house site chosen—near the junction of Penn Avenue and the Pennsylvania Railroad—is approximately the center of the system, extending as it does about two miles in every direction from this point. Although the Pennsylvania Railroad passing the property offered excellent fuel facilities, the absence of a natural supply of water in the East End practically barred a steam plant. The high pressure pipe line of the Pittsburg Natural Gas Co., delivering 24,000,000 cu. ft. of gas daily to the mill district of this city passes within 1000 ft. of the power house site, and this fuel was finally decided upon for its availability and cheapness. Should the natural gas ever fail or reach a prohibitive price, a producer plant will be erected on the company's adjoining property, the coal used being elevated from the Pennsylvania Railroad tracks. In this case the present engine equipment will be retained, as it is entirely adapted to either natural or producer gas—a good illustration of the flexibility of power gas work. In the building proper—a sub-station fire-proof structure of brick, concrete, and steel—the one feature out of the ordinary is that the entire building is devoted to generating machinery, no boiler or producer room being necessary. When complete with four units, the station will total but 3.7 sq. ft. per rated kilowatt, a low figure for a plant of only 720 kw. capacity.

EQUIPMENT.

Generating units. Each of the two generating units at present installed consists of a three-cylinder, vertical, single-acting gas engine, with cylinders 18 in. in diameter by 22 in. stroke, running at 200 rev. per. min., direct connected through a flexible spring coupling to a 180-kw., engine-type, 60-cycle, alternating-current generator. These units are of standard construction and include the very best features for obtaining satisfactory parallel operation, uniform speed under variable loads, continuity of operation, and low operating expense.

Auxiliaries. The auxiliaries include apparatus for supplying compressed air for starting the engines, 4-volt and 110-volt direct current for ignition purposes, 110-volt direct current for exciting the main generators, and water for cooling the engines.

*A paper read before the American Institute of Electrical Engineers, Pittsburg Branch, May 14, 1907, by Norman C. MacPherson.

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Compressed air supply. The compressed air supply for starting the engines must be independent of the engines themselves, as it must be ready for use when the rest of the station is "dead." For this purpose, a small horizontal, single-acting gas engine is used, which is belted to a two-stage compressor; for breakdown purposes, a separate compressor is installed, belted to a counter shaft which in turn can be driven by either of the main engines. The supply of air normally needed for starting the engines, is stored in two 16-in. cylindrical tanks at 200 lb. pressure. In addition, four more of these tanks, each controlled by its own valve, have been installed, which, as they are not to be drawn from except for emergency work, constitute a reserve for the engine-driven compressor. The six tanks total 102 cu. ft., or over ten times the cylinder displacement of one engine.

Ignition current. For initial ignition, there has been provided one set of primary "dry" batteries and one set of storage-batteries, either of which is sufficient to operate the plant for some time. For ordinary use, however, a motor-generator set has been provided, taking current for its motor from 110-volt, direct-current, exciter bus-bars, and delivering from its shunt-wound generator, direct current of the same voltage. This supplies current to the ignition points which are operated in series with suitable resistance lamps. The storage batteries, however, are connected inside the lamps and work directly on the ignition points, thus allowing the batteries to "float" on the circuit, at all times fully charged and ready automatically to furnish the ignition current in case of accident to the motor-generator. Whenever necessary the 110-volt exciter circuit can be thrown directly on the same resistance lamps,

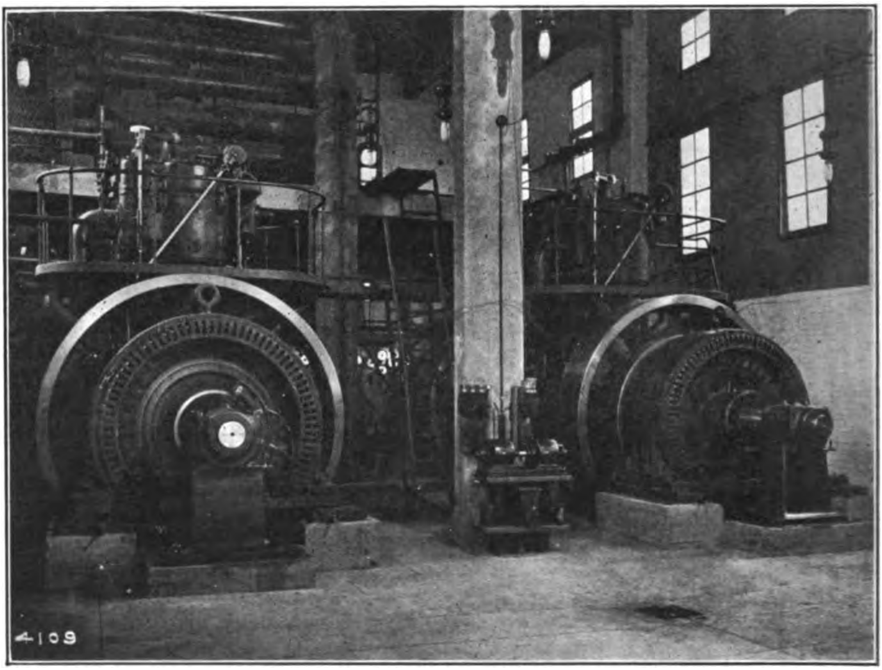

FIG. 1.

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but this has the drawback of permanently grounding the one side of the field winding of the alternating-current generators.

Excitation. The direct-current excitation for the main generators is provided by two 110-volt, compound-wound dynamos, either of which has sufficient capacity for both of the main units. These exciters are direct connected to induction motors which, in turn, are fed directly from either set of main switchboard bus-bars. These motor-generator sets are also provided with pulleys for belt connection to a counter shaft which, in turn, can be run by either of the main engines through friction clutches. This clutch and belt device is occasionally a decided convenience in different ways, but its normal and important use is only for a few minutes, namely, after an accident has deadened the main alternating-current switchboard bus-bar. In this case the first main generator secures its excitation by means of an exciter set driven by its belt; the main generator is then switched on the bus-bars and supplies current to the induction motor of the other exciter set. Next, the exciters are paralleled, the load transferred to the second exciter, and finally the friction clutch driving the first exciter set is released.

Cooling water. The simplest method of cooling the cylinder jacket is, of course, to use fresh water directly from the city mains; this method, however, is rather expensive, and a circulating system has been installed which permits the use of a given quantity of city water over and over again until its temperature is too high. For this purpose, a two compartment concrete tank has been constructed on the roof of the building, provided with overflow and risers, connecting with engines and city water piping. In these roof tanks a sufficient amount of surface cooling has been obtained to reduce the quantity of water required by the plant to about one-half of that needed without this circulating system, and this proportion will be still further reduced by a simple form of cooling tower now being constructed on the roof. For emergency use, it is proposed to employ well water, although impurities will not permit its steady use. The jackets do not work under full pressure head from the tanks, about 35 ft., but deliver into a supplementary tank located on the mezzanine floor of the engine room, giving about 5 ft. of pressure head on the engine jackets. This is sufficient to provide solid water at all points and to prevent air pockets. From this tank, a centrifugal pump driven by a three horse-power induction motor, delivers this water to the roof tanks.

Piping. The engine exhausts are carried out through the building walls with easy bends, and then rise 40 ft. to clear the roof. As water is used in the exhausts, these risers are drained near the engines. A simple steam exhaust head capping each riser completely deadens the exhausts, thus avoiding the difficulty sometimes experienced with gas plants located in residence territory.

The gas is delivered at the power house at about 15 lb. pressure, but this is reduced to 8 ounces before being metered. This pressure is further lowered to two ounces by the regulators furnished with each engine. Ample storage capacity in the shape of liberal piping, has been provided on both sides of the engine regulators to insure a moderately uniform flow of low-pressure gas.

OPERATION.

Parallel operation and regulation. As this is a 60-cycle, polyphase plant, carrying a mixed load of lights and motors, it is apparent that good voltage regulation is necessary and that satisfactory parallel operation is an indispensable feature. The very fact that the plant is able to give so good a quality of service is proof that the parallel operation bugaboo held over the gas engine for years, has been driven to cover especially with direct-connected 60-cycle generators. These units are

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paralleled in precisely the same manner as the ordinary steam unit, on an "opening throttle;" that is, the new unit is brought slowly up to synchronism with the one in service, and after the switches are closed, the throttle is spun open. There is an important advantage, however, over a steam engine of ordinary construction; namely, that the tension of the governor spring may be easily changed by hand while the engine is running, thus changing its speed and consequently its load also. As a matter of fact, instead of altering the governor spring, a pair of springs at the mixing valve working against the governor spring is adjusted, thus securing the same result. This adjustment, consisting simply of a pair of thumb screws, gives an opportunity to bring up the load on the new unit as slowly or as rapidly as desired, and to any point. Thus the fresh unit may be given more than its share of the load for a time to relieve the temperature of the other; or should an igniter on either engine give trouble, the load may be dropped to two-thirds rating without taking the unit out of service. This adjustment is also sometimes used to bring the engine into synchronism. The effect of a misfire in one of the cylinders is never noticeable on the line, except when the misfire continues for several cycles, which is rare. Naturally, it induces some little surging between the two machines, owing to the temporary disablement of a cylinder, but the shock is readily absorbed by the spring coupling and does not show the slightest tendency to throw the engine out of step. In general, the regulation from this plant is fully as good as could be expected from any steam plant, and is entirely due to the method of controlling the quantity of mixture by the governor, which is a fundamental feature of the four-cycle gas engine.

Ignition. This is one of the most vital points in gas engine work and should receive careful attention from both the designing and operating engineer. There should be at least two separate sources of ignition current continuously available, which are provided for here by the small 110-volt shunt-wound generator and the set of 4-volt storage-batteries, as before described. Only one case has occurred where an engine has been shut down from the loss of igniter current, and this was due to a ground in the conduit between igniter switchboard and engine. This occurred in spite of the precaution of running all wiring through loricated iron conduit. A few spare igniters are always kept on hand, and it is only a few minutes work to replace a disabled one. If, however, these are changed regularly and cleaned, as they should be, they give very little trouble. On these engines there is a device for changing the point of ignition while running. It is very necessary in gas engine work that ignition take place at the proper point, otherwise inefficient combustion shown by a badly distorted card, will result. But a good engineer can very readily determine whether the ignition is at the right point merely by the sound of the explosion. Should the gas change in quality for any reason, the ignition can be readily adjusted, as well as the mixture, in a few seconds, without in the least disturbing the running of the engine.

Starting. One very great advantage of gas engine work is the absence of standby losses after the engine is shut down, unlike the steam plant where there are condensation, radiation, and stack losses. The gas engine may stand for an hour or a month without incurring any losses whatsoever, and yet be in readiness for starting within a minute or two of the signal; but a steam engine must be warmed up and "turning over," previous to loading. In the Duquesne plant, compressed air is used for starting the engines. A supply several times greater than that actually required is always kept stored in steel tanks at 150 lb. pressure. A single air valve controls each engine, and as soon as the air is turned on, the

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engine automatically comes up to speed, usually in about 45 seconds, so that the unit may be loaded within about one minute from the start, or at least two minutes. This is evidently a good feature in case of emergency spare units.

Station efficiency. A power station is, in one sense, only a machine for converting the potential heat energy of fuel gas or coal into electrical energy. The efficiency of conversion depends almost entirely upon the type of plant. With steam engines, four pounds of coal per kilowatt-hour may fairly be assumed to be well above the average results obtained in lighting plants of less than 1000 h.p. capacity. Now four lbs. of bituminous coal of 14,000 B.t.u. per lb. (equal to 53.3 cu. ft. of natural gas of 1050 B.t.u. per cu. ft), is equivalent to a heat consumption of 56,000 B.t.u. per kilowatt-hour at the switchboard, or an absolute thermal efficiency (1 h.p. = 2545 B.t.u.) of 6.1% between coal pile and switchboard.

Fig. 2 shows the fuel consumption of the Duquesne Light Company's engines, and displays the total hourly gas per engine, the gas per kilowatt-hour and the absolute thermal efficiency from gas to electricity. The "total gas" curve, from which the others are calculated, was determined by reducing the actual station records to the equivalent performance of a single engine, and it has been checked up by a number of readings taken at various loads. We will tabulate, for illustration, the values for two different engine load-factors; namely, 40% and 80%. These are extreme limits—a plant requiring five engines to carry its peak load, should be able to operate at an average engine load-factor of 80% and a plant requiring two engines for its peak load, would probably run with an average engine load factor of 40%.

Summarizing the tabulation, we find that natural gas of 1050 B.t.u. per cu. ft. will give a kilowatt-hour on 21.2 cu. ft., with an average engine load-factor of 40%; if the engines can be run on an average load-factor of 80%, the gas required will be only 15.2 cu. ft. per kilowatt-hour. These values can be reduced, for sake of illustration, to equivalent pounds of coal having 14,000 B.t.u. per pound; namely, 1.7 and 1.23 lb. per kilowatt-hour, respectively. If it is desired to compare these results with steam data expressed in terms of indicated horse power, these values will be approximately 0.96 and 0.78 lb. respectively.

Engine load-factor	Cu. ft. gas per kw-hr.	B.t.u. per kw-hr.	Absolute efficiency of unit (gas to electricity)	Equivalent coal B.t.u. basis lb. per kw-hr.	lb. per i.h.p-hr.
40%	21.2	22,200	15.35%	1.7	0.96
80%	15.2	16,000	21.4%	1.23	0.78

The comparison of the fuel consumption of the steam station described above, (operating on an equivalent of 53.3 cu.ft. of natural gas per kilowatt-hour) with the gas rate of a gas engine station which lies somewhere between the limits of 21.2 and 15.2 cu. ft., is a striking illustration of the great fuel economy of the gas engine, and is, in itself, a measure of the relative thermal efficiencies of the two methods of developing power from natural gas.

Cost of power. All the various items entering into the cost of power are, at present, difficult to obtain in segregated form, but have been estimated as closely as possible from two different prices of gas.

	25c. gas		15c. gas
	% of total	cents per kw-hr.	cents per kw-hr.
Fuel gas.......	47.6	.440	.264
Wages.........	28.3	.260	.260
Supplies:			
Oil waste. 11.3			
Water....9.0			
	20.3	.187	.187
Repairs........	3.8	.026	.026
Totals......	100.	.913	.737

This estimate, based upon the present load-factor and the complete plant,

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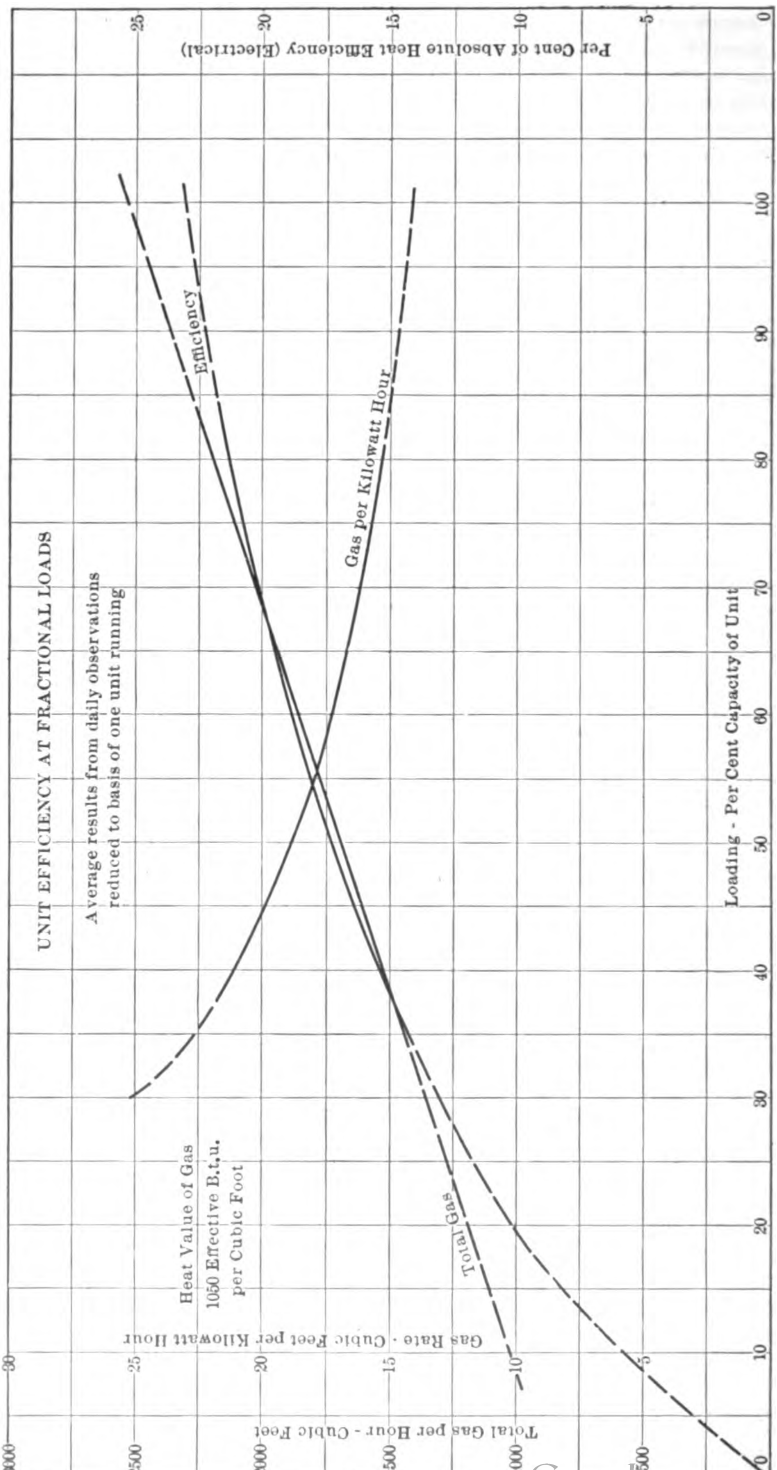

FIG. 2.

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shows a total operating cost well under 1c. per kilowatt-hour for the highest priced gas, and 0.75c. for the lowest.

In the near future, this will be somewhat lowered by a reduction in the cost of water due to the cooling system mentioned above. Such a low cost shows the possibility of developing a large daylight power load, which feature appeals strongly to electric light managers.

It is difficult to compare these fuel costs per kilowatt-hour with those of ordinary steam plants, as so much depends upon the character of their service and apparatus, but a large number of electric light plants under 1000 horse power will have a fuel consumption varying between four lb. and eight lb. of coal. It is also fair to assume that their expenses, outside of the fuel item, will not differ materially from those given above (in a great many cases their wage item will materially exceed 0.26c. per kilo.watt-hour)

On this basis, then, natural gas at 25 cents per 1000 cu. ft. is competitive with coal at $2.20 per ton, on a consumption of 4 lb. per kilowatt-hour, also with $1.10 coal, on the basis of eight lb. per kilowatt-hour. Similarly, 15c. gas is competitive with coal at $1.32 per ton with a coal consumption of four lbs. per kilowatt-hour and with coal at 66c. a ton on a consumption of 8 lb. per kilowatt-hour.

Conclusion. It is well to keep clearly in mind that a gas power station can utilize to better advantage a larger number of generating units than can a steam station. The reason for this is that the gas engines are practically as efficient in small as in large sizes, and that the cost per kilowatt, and floor space occupied per kilowatt of rating, is likewise nearly uniform. Consequently, it is better to split up the station capacity as much as possible, thereby enabling the operator to fit his units into the load curve and obtain a better efficiency for the station. The available spare power will also be better distributed, and this multiplicity of units more readily provides for the possibility of losing an igniter. With one unit running, the disablement of one cylinder amounts to 33% of the rated capacity; with two units running this deficiency amounts to 16.6%; with three units, the deficiency is reduced to a little over 11% of the total capacity in operation. With four units running, the deficiency is but 8%, which can be readily taken care of by the overload capacity of the remaining cylinders.

General experience with the Duquesne Light Company's plant thus far indicates that good service, combined with low operating costs, may be expected if proper attention is given to keeping the equipment in good working order. It is true that inexperienced or careless men cannot get the best results from a gas equipment, but with an experienced, active engineer in charge, the equipment is as trustworthy as a steam plant.

Discussion

J. R. Bibbins: This paper, dealing as it does with the most recent form of motive power, affords an interesting study and presents many old problems in a new light. One of the most important is the question of relative spare capacity. In planning a new station, this question arises right at the outset after the problematical load curve has been determined upon—how many, and what size of units will be installed. Although one or two units yield the simplest form of plant, when one considers the average running efficiency the unit will give under the given load-factor it is a different matter.

In a recent study of this point, a 1000-kilowatt maximum load curve was assumed with 1, 2, 3, 4, and 5 service units and a single spare unit. By " blocking in " the engine curves corresponding to the actual capacity in service at a given time, the average load on the engine was obtained in per cent. of its rating, this being obtained by integrating both load and engine curves. Thus the relative heat consumption under average running con-

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ditions was obtained. For this particular load curve the first three unit combinations worked out best in horizontal units, the last two in vertical. For five units this condition works out to an average heat consumption of less than one-half that required by a single unit; in other words, an efficiency of twice as great. As to the cost of spare capacity for the single-unit plant, we must provide a spare unit equal to the running capacity—100%, two units, 50%, etc., down to 20% for five units.

It may be contended that the relative heat consumption and the cost of spare capacity are only small factors in the final solution of the problem, but this is not the case. The modern gas engine requires, in the larger sizes, a type of construction which does not permit of very great reduction in cost over smaller sizes which embody the vertical self-contained construction. It thus develops that the price of a large gas-engine unit is very little lower than that of a medium sized unit. Again, we find that the heat efficiency of the large unit is but very little higher than that of the smaller sizes, due largely to the inherent properties of the combustion cycle rather than to any precise refinement in design or construction which so clearly disclose the character of steam engine construction. Analyzing the labor cost in the station, we find that with the compact, self-contained, vertical unit, this item is very nearly the same as for equivalent horizontal capacity. Thus the problem practically reduces itself to that of relative operating efficiency and investment in spare units with the result above noted.

On the question of spare units we may assume as a possible contingency that an igniter will give trouble at some time. This throws a certain part of the engine out of service, but does not necessarily disable it. With one unit running, the loss of an igniter would cause 25% loss of power, and with five units, 6.6% but on the standard overload ratings each engine cylinder is capable of delivering 10% overload continuously. This overload capacity thus comes to the rescue of the disabled igniter. With two running units in the plant, we will barely be able to carry full load; with three units the extra capacity will tide us over; with five units the plant will develop 2.7% in excess of the rating in spite of the disabled igniter.

An overload capacity of 10% seems small compared with the similar capacity of a steam engine or steam turbine unit. While a steam unit gives its best economy at full load or under, the economy of the gas engine increases up to the maximum load, which makes it desirable to rate the engines and operate them as close to maximum as is permissible, and while the gas-engine has a decided advantage for steady central station service, it is somewhat at a disadvantage on rapidly fluctuating loads. This, however, may be overcome by the use of a storage-battery. A system has recently been devised by which the generator load may be held practically constant while the entire fluctuating load may be taken up by the battery. This is accomplished by a load regulator, a simple instrument of the relay type, installed on the switchboard and operating in connection with the booster. In a recent test with this system, the external load was instantly varied through a range equivalent to 300% of the generator capacity, yet these variations were entirely absorbed by the battery, and the generator kept within a few per cent. of its rating, irrespective of the suddenness or the violence of the fluctuations. This instrument is particularly useful in gas engine work as it permits full loading of the unit with impunity whereas it might be necessary to reduce the average loading to one-third of the rating in order to take care of the fluctuations.

It is interesting to compare the efficiency of the small plant Mr. McPherson has described, with the very large central stations now operating with

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steam. The absolute thermal efficiency of a station of 50,000-kw. capacity, equipped with the largest and best type of steam engines built, is about 10%. This little gas-driven station is giving an average of 20%, and, when running at full load, still higher. This is the total conversion efficiency from heat in the fuel to power at the switchboard, and shows one of the great advantages of gas engine work.

Finally may be mentioned the extreme flexibility of gas power. In steam practice we are chiefly confined to coal as fuel. We have used coal gas (which is rather expensive, but can be found in every city). A 500 h.p. engine at Lebanon, Pa., is now operating on coke-oven gas, a by-product of the coking process. A 2000-h.p. plant at Philadelphia is running on oil distillate, a product of the oil-refining process. In California a gas made from crude oil, called crude-oil water gas, is used. Its efficiency is not so high as could be desired, but it is a great improvement over steam. At Bessemer, a 5000-h.p. plant is operating on blast-furnace gas. Finally, we have gas made from bog peat. This fuel is coming to the front in New England where peat is found in large quantities and is easy of access.

What promises to be the most promising field, is low-grade anthracite. Every visitor to the anthracite field is at first astonished at the great waste of coal. In the Hazelton mining region, the speaker saw one bank containing 200,000 tons of comparatively large block coal. Another had 150,000 tons of what is called rice and barley. Neither could be marketed to any extent. The former was mined when only the very best coal was sent out to the market, and was considered waste. At that time operators wasted about 60%, and sent 40% to the market; now the waste is but 10%. Recent tests at east Pittsburg show that we can use this fuel very successfully in gas producers down to as small as the sizes known as "rice" and "barley." This is worth $0.60 a ton at the mines, and can be obtained in Boston at $2.50, where the market price of good steam coal is $3.85 to $4.00 a ton.

Suggestions to Authors Regarding the Preparation of Copy for Cuts Used in Illustrating Institute Papers

As probably in nine cases out of ten, papers presented before the Institute are illustrated with cuts of various kinds, it may not be amiss here to make a few suggestions in regard to the copy for cuts intended to illustrate a paper or a discussion. The cuts used in the Institute PROCEEDINGS and TRANSACTIONS are of three kinds; half-tones, line-cuts, and wax-cuts.

Half-tones. Half-tones are made from photographs. The best effects are obtained from what is known as a solio print, with a slightly reddish tone. The print should be clear enough to make "retouching" unnecessary, as this is an expensive and time-consuming process. Particular care should be taken to see that the photograph will stand reducing to the size necessary to fit the measure of the Institute TRANSACTIONS. This measure is four inches on the horizontal, seven inches on the vertical.

Line-cuts. Line cuts are made by a direct photographic process. To get the best effect, the copy must be able in every way to stand reducing to four inches on the horizontal, or seven inches on the vertical. The lettering should be exceedingly clear, so that when reduced there will be no difficulty in reading it. It is preferable to make cuts containing curves by this process, a process that takes but a short time and costs about five cents per square inch. Unfortunately, it is not always possible to do this, owing to the prevalence of one or more of three conditions. First, the illustration is too sketchy to be photographed properly;

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secondly, the lettering is not of the right size or quality to reproduce in conformity with the standard of the Institute in these matters; thirdly, and contrived to foist upon engineers paper ruled with light blue, light green, light brown, yellow, or red lines with the cross-sectioning much too fine for ordinary

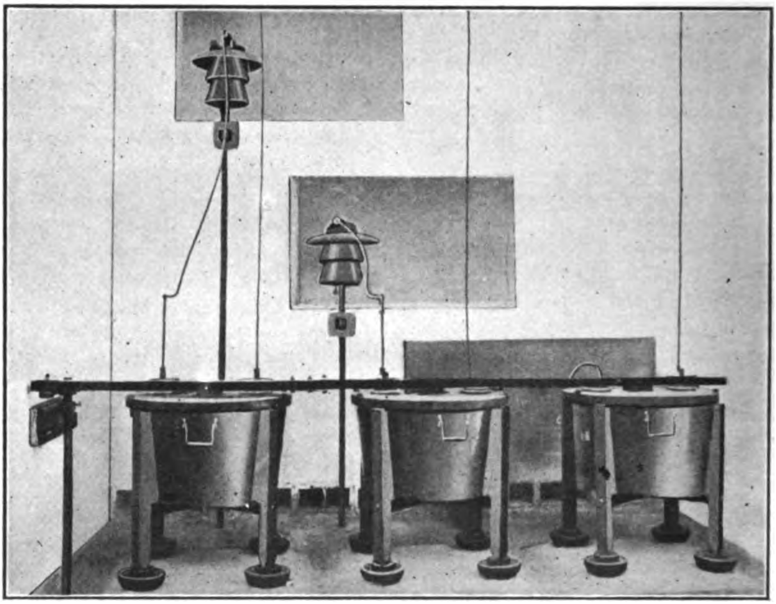

FIG. 1—A fairly clear half-tone cut made from slightly retouched copy

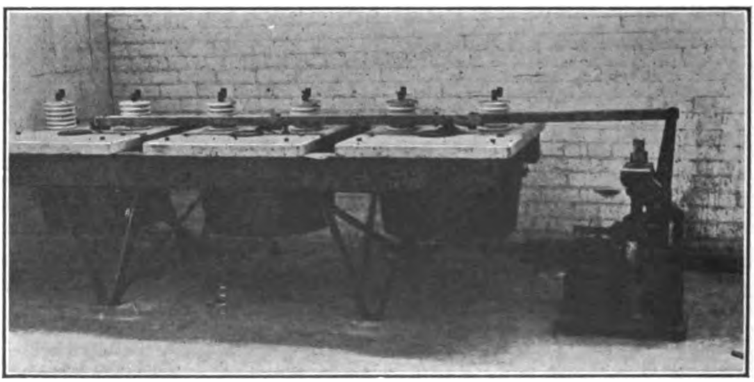

FIG. 2—A poor half-tone cut made from indistinct copy that could not safely be retouched

most important of all, the cross-section paper used makes exceedingly poor "copy" For one reason or another the makers of cross-section paper have purposes. Frequently, engineers need only every fifth or every tenth line as coördinates in locating the points which determine the curve; it is seldom

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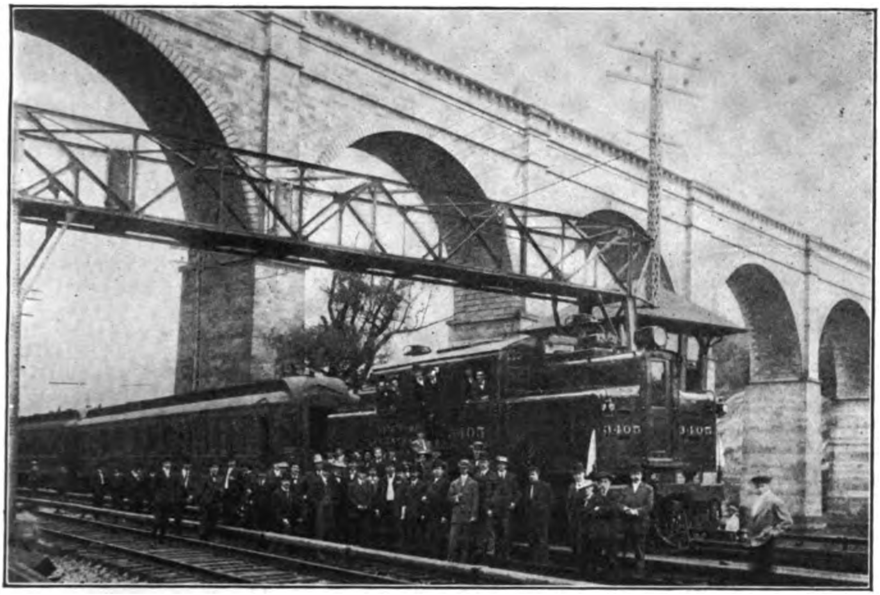

FIG. 3—A reasonably good half-tone, reduced to one-quarter of the original size; no retouching

that the intermediate lines are needed. In reproducing a curve by the "line-cut" process from copy consisting of minutely subdivided cross-section paper with light brown or green or yellow or red lines, all the unnecessary subdivisions on the cross-section paper appear in the cut, giving at best an indistinct or hazy impression. See Fig. 5. If the cross-section paper used were ruled

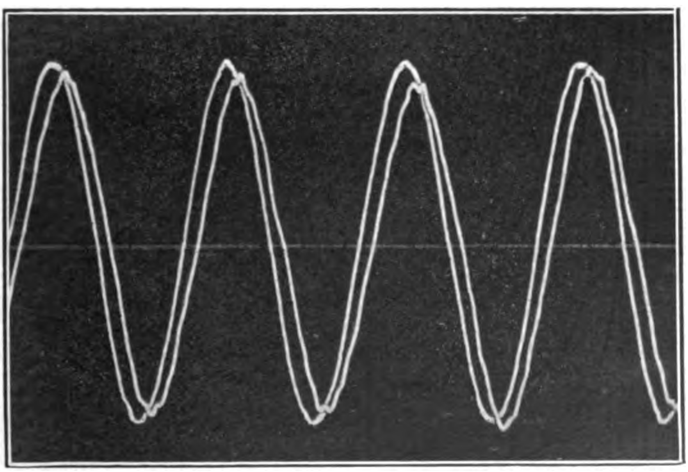

FIG. 4—Half-tone of oscillogram, made from poor copy carefully retouched. Under present conditions it is almost impossible to make satisfactory cuts of oscillograms without retouching the copy

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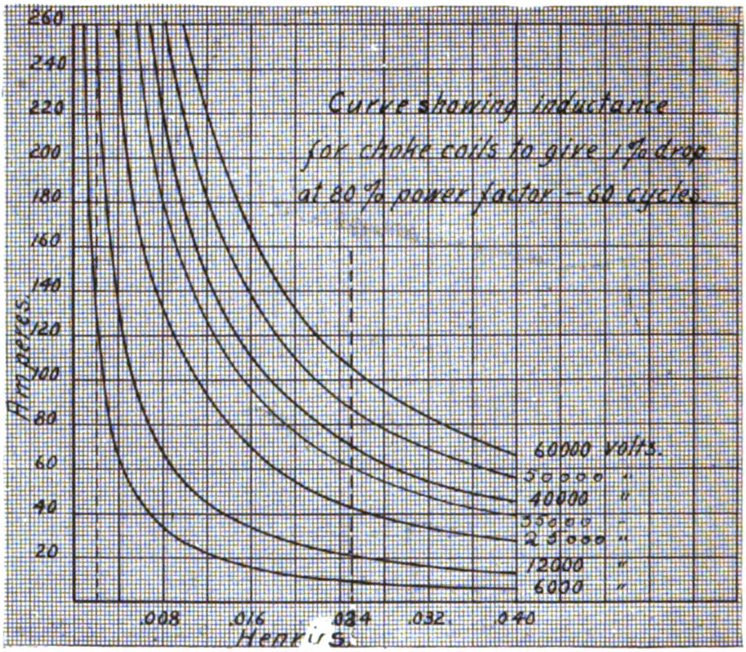

FIG. 5—Line-cut made from cross-section paper ruled with light brown lines. All the fine cross-section lines are reproduced, giving a hazy impression. The same hazy effect is produced in line-cuts made from copy with yellow, green, or red cross-section lines

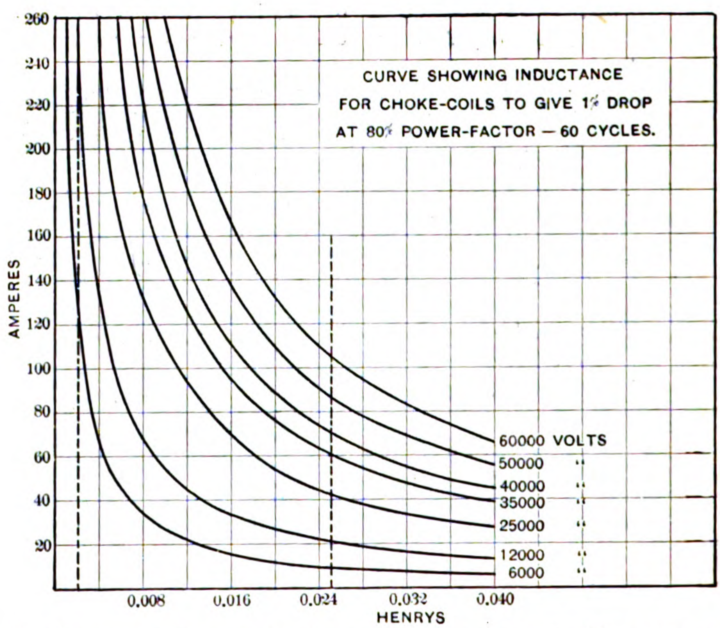

FIG. 6—The same cut, made by the costly wax process. This cut cost $2.80

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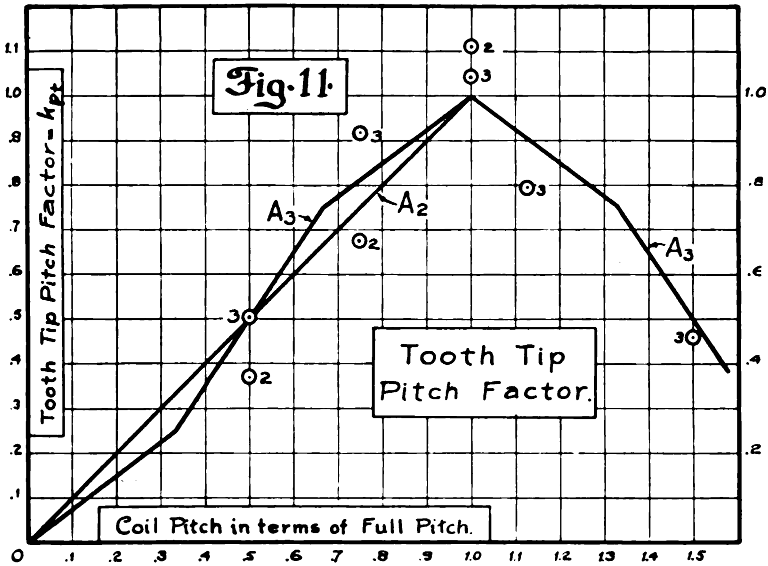

FIG. 7.—Line-cut made from good copy on blue-line cross-section paper with the necessary cross-section lines inked in. This cut cost 60 cents

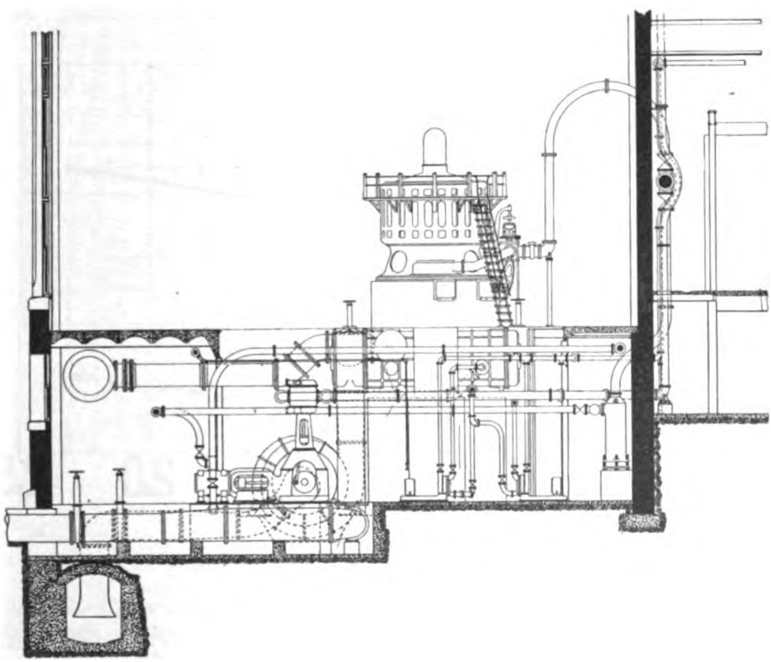

FIG. 8—Line-cut made from poor copy, and considerably reduced in size

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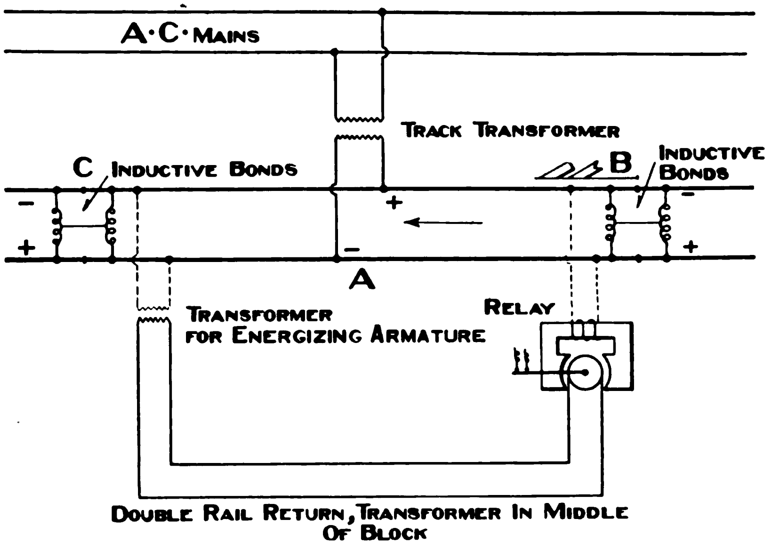

Fig. 9—Line-cut made from original tracing; tracing substituted for blue-print by request

with light brown, green, yellow, or red lines showing only the coördinates actually needed to determine the points of a curve, this unsatisfactory condition would be avoided; process that requires time and money.

It is common practice to use cross-section paper ruled with light-blue lines. As blue does not photograph at all, it is impossible in the present state of

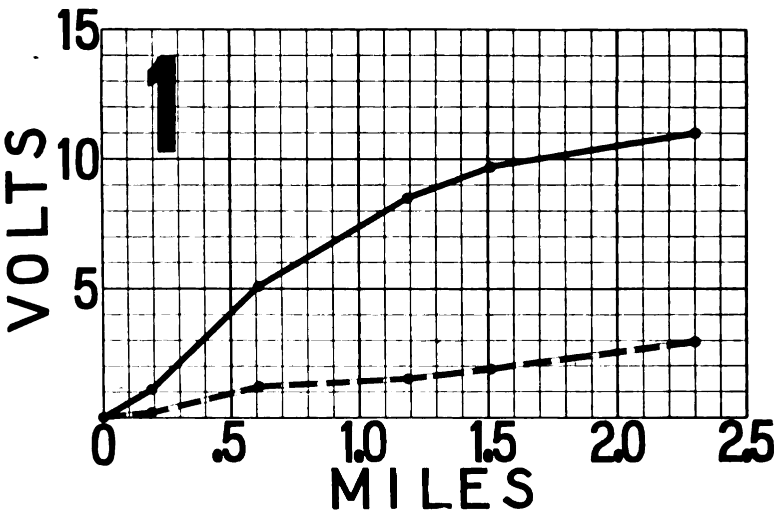

Fig. 10—A good line-cut from good copy, but lettering somewhat too large

but as this kind of cross-section paper is virtually not used at all, to avoid getting an indistinct impression this faulty copy must be reproduced by the wax-process, a the art to reproduce with this kind of cross-section paper the necessary coördinates that determine the character of the curve. Curves on this kind of paper could be reproduced quickly

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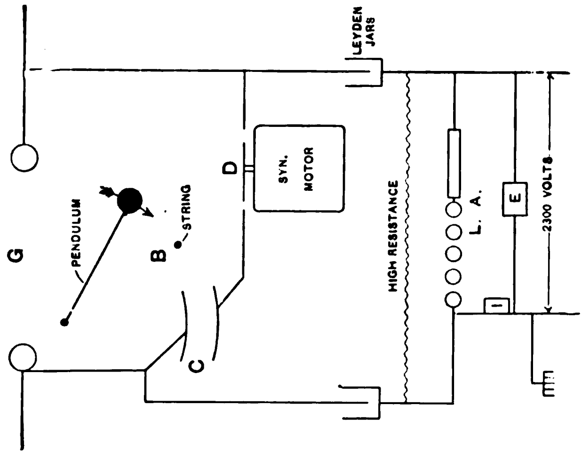

FIG. 11—Wax-cut made from a hastily prepared pencil sketch. This cut cost $2.00; a similar line-cut could be had for 50 cents

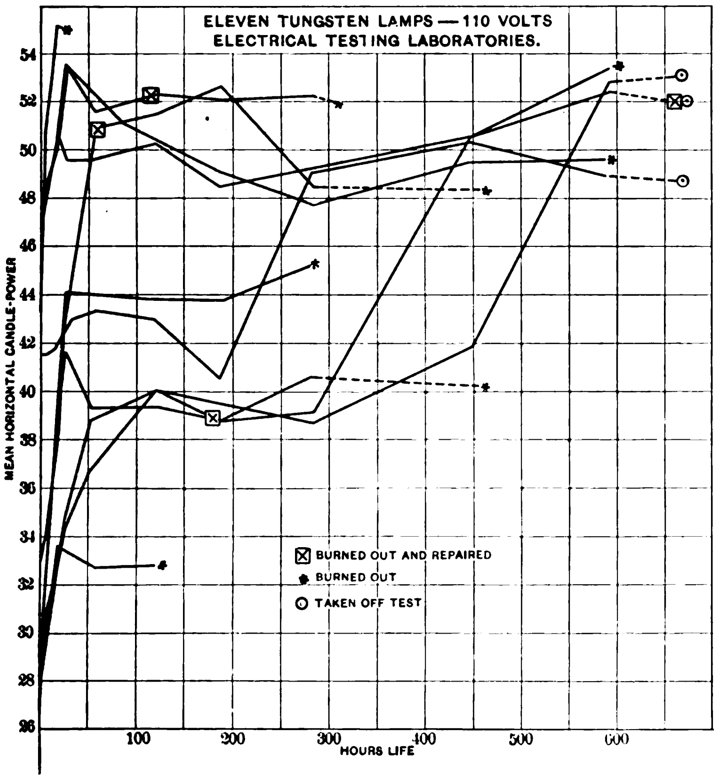

FIG. 12—Wax-cut made from good copy on cross-section paper ruled with light-brown lines. As all the fine cross-section lines would appear in the impression from a line-cut, thus blurring it, the wax process was resorted to. The cut cost $3.20. The same kind of copy on blue-line cross-section paper, with the necessary coördinates inked in, would cost only 80 cents

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and cheaply if the author would letter the copy carefully and then trace in black ink the coördinates that he wishes to appear in the cut.

By the line-cut process, then, costing only five cents per square inch and requiring only a brief time-element, entirely too many coördinates appear in cuts made from cross-section paper so that the drawing will stand reducing to four inches on the horizontal or seven inches on the vertical.

Wax-Cuts. Wax-cuts cost twenty cents per square inch, four times as much as line-cuts, and take about five times as long to make. The Institute has been put to a great deal of expense, and has been delayed a number of times in print-

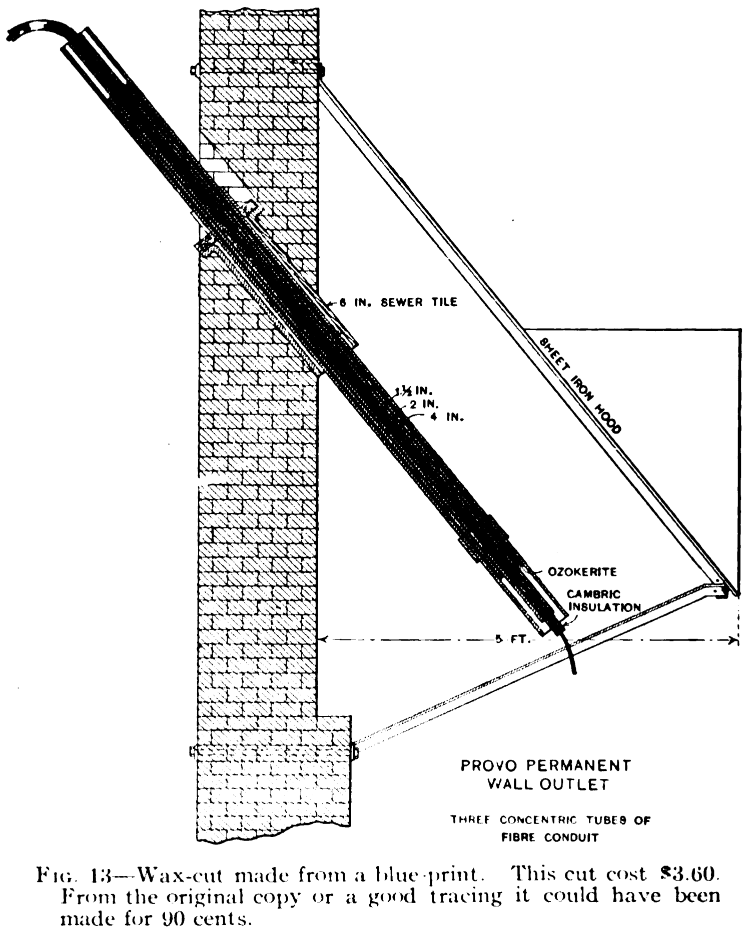

FIG. 13—Wax-cut made from a blue-print. This cut cost $3.60. From the original copy or a good tracing it could have been made for 90 cents.

ruled with light-brown, green, yellow, or red lines; no coördinates at all appear in cuts made from blue-line cross-section paper. The best plan is, then, to draw the curve on blue-line cross-section paper, inking in the necessary coördinates, and carefully lettering the sheet ing advance copies of papers, because it has been compelled to resort to this process in order to reproduce improperly prepared copy for cuts. As explained above under the heading, "Line-cuts," considerable money and time and some annoyance can be saved by explicitly following the directions

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regarding the making of curve sheets on blue-line cross-section paper with the necessary coördinates properly inked in. Drawings other than curves are usually sent in either as pencil sketches, or in blue-print form. In both of these cases the wax-cut process must be resorted to in order to reproduce the drawings. If, instead of pencil sketches or blue-prints, authors would send the original tracings, properly lettered to conform with Institute style and qualified to stand the necessary reducing, all these cuts could be made by the line-cut process at five cents per square inch, instead of by the wax-cut process at twenty cents per square inch.

The Presentation of Papers Before the Institute

For the benefit of those who desire to present papers before the Institute during the coming year and who may not be wholly familiar with the rules and customs of the Institute in such matters, the following explanation is given.

Although the advantage to the electrical profession of the stimulus, the educational influence and the development of *esprit de corps*, due to the influence of the Institute, is important and far reaching, yet the most serious direct effort of the Institute is the publication in its PROCEEDINGS and TRANSACTIONS of the fullest view of current electrical progress. Consequently, opportunity is gladly given for the presentation of all valuable matter of interest to the electrical profession when presented in the proper form.

According to the amended Constitution, the arranging of meetings, and the editing and approving of papers, lies with the Meetings and Papers Committee; all correspondence relating to papers should be there addressed.

Any person desiring to present a paper should so inform the committee as early as practicable, as the meetings are arranged some time in advance. It is the general plan of the committee not to assign dates for the reading of papers until the manuscript is received, so that papers may be published in full some time before the meeting to allow a careful preparation of discussion.

As the comments and criticisms on the papers, when well considered, generally add much to the value of the meetings, a few persons having especial authority or special knowledge are invited to start the discussion, which afterwards is thrown upon.

Written communication on any paper will be received within a reasonable time of the meeting, either before or after.

There are certain limitations as to what is generally considered to constitute proper subject matter for presentation before the Institute.

(a) Only original papers will be received, *i.e.*, papers previously published elsewhere cannot be presented before the Institute. Exception will be made in the case of the Institute Sections.

(b) Except in special cases, only matters of interest to a considerable portion of the Institute body can be presented at the regular monthly meetings. Other valuable matter will usually be reserved for the annual convention, or for special meetings.

(c) No matter intended *merely* to advertise any person or any particular make of apparatus is admissible.

(d) Space cannot usually be given to papers that are merely descriptive of apparatus or plants which do not involve new features or important data not elsewhere available.

(e) Papers should as far as possible conform to the directions provided by the Meetings and Papers Committee as to typographical form, the use of abbreviations, character of cuts, etc. Copies of these directions can be obtained from the Committee, or from the Secretary of the Institute.

In all cases papers are subject to revision or rejection by the Meetings and Papers Committee.

It is earnestly requested, to permit of the most satisfactory arrangement of the program for the Institute meet-

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ings, and to lighten the work of the Committee, that all members contemplating the presentation of papers will give the earliest possible notice of their intention, and also complete the preparation of their manuscripts and send them to the committee promptly. It is probable that papers offered when the season is well advanced cannot be presented at any of the regular meetings during the present year.

PERCY H. THOMAS,
Chairman Meetings & Papers Committee.

Sections and University Branches

TOLEDO SECTION

The regular monthly meeting of Toledo Section of the American Institute of Electrical Engineers was held Friday evening, September 6, 1907, at the Boody House. In the absence of Chairman Nagel, Secretary Geo. E. Kirk presided.

Mr. Geo. J. Miller gave a very interesting talk on the history of the electric storage-battery, explaining the basic features of chemically formed and pasted plates. The rough usage to which batteries are subjected, as in automobile work, was pointed out, and how plates are designed to give efficiency and durability even under such trying circumstances. Specimens of different plates were shown. There was a general discussion.

BY-LAWS OF THE TOLEDO SECTION

I. NAME—Under the Constitution of the American Institute of Electrical Engineers, and pursuant to authorization of its board of Directors May 21, 1907, this Toledo Section of the American Institute of Electrical Engineers is organized.

II. OFFICERS—The officers of this Section shall be a chairman, secretary, and three additional members constituting an executive committee of five.

1. Election of officers. The members of the Section shall vote by ballot for the five members of the executive committee.

2. Term of office. The executive committee shall be elected at the regular January meeting of each year for a term of one year.

3. Meetings of the executive committee. The executive committee shall meet wherever called by the chairman or a majority of its members.

4. Organization of executive committee. The chairman of the Section shall be chairman of the executive committee and the secretary of the Section shall be secretary of the executive committee.

III. MEETINGS. The Section shall hold a regular meeting at 8:00 p. m. on the first Friday of each month at such place as the secretary may designate in the notice. Special meetings may be held upon call of the chairman or a majority of the executive committee, details as to time and place to be given in notice.

IV. GOVERNMENT. In deciding questions of government of Section and procedure therein, the Constitution of the Institute, the By-laws of the Institute, these By-laws of this section and Robert's Rules of Order, shall be followed in the order named.

V. AMENDMENTS. These By-laws may be amended by a majority of the members present at any regular meeting held after notice has been given that the amendment is to be considered.

VI. ADOPTION. These By-laws shall be in force when adopted by a majority of the members present at regular September 1907, meeting.

Associates Elected

At a regular meeting of the Board of Directors held in the Engineers' Building, 33 West Thirty-ninth street, New York, Friday, September 27, 1907, at 3:30 p.m., the following 60 Associates were elected:

ASHWORTH, EDWARD MONTAGUE, Engineer, Canadian General Electric Co.; res., 1584 Brunswick Ave., Toronto, Ont.

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BALDAUF, GUSTAV, Superintendent, Arc Lamp Factory, Allgemeine Elektricitats Gesellschaft, Berlin N., Germany.

BEAUBIEN, JAMES DE GASPE, Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg; res., 427 Centre St., Wilkinsburg, Pa.

BLACK, ALEXANDER LESLIE, Engineer, New Orleans Railway and Light Co., 323 Baronne St., New Orleans, La.

BLISS, ELMER FRANKLYN, Engineer, Railway Signal Department, General Electric Co.; res., 104 Campbell Ave., Schenectady, N. Y.

BLIVEN, CHARLES M., Agent, General Electric Co., Union Trust Bldg., San Francisco, Cal.

BORGE, OLAF, Electrical Engineer, Norsk Elektrisk Aktiebolag, Skovveien 12, Christiania, Norway.

BOWRING, CHARLES THURSTON, Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg; res., 410 Todd St., Wilkinsburg, Pa.

BRIGHAM, VERNON THEODORE, Assistant Instructor, Electrical Engineering Department, Purdue University, Lafayette, Ind.

COLLENS, CLARENCE LYMAN, 2d, Assistant Superintendent, Canadian Niagara Power Co., Niagara Falls, N. Y.

CONNOLLY, ALEXANDER C., Engineer, Electrical Construction, Mexican Light and Power Co., Apartado 905, Mexico, D. F. Mex.

COOPER, THOMAS, Westinghouse Electric and Mfg. Co.; res., 909 So. St. Bernard St., Philadelphia, Pa.

DAVIS, CLARENCE ALBERT, Telephone Engineer, Western Electric Co.; res., 153 E. 86th St., New York City.

DAY, LEONARD, Patent Lawyer and Patent Expert, with N. M. Goodlett, Jr., 2 Rector St., New York City.

DEATH, NORMAN PERCIVAL FREDERICK, Assistant Engineer, C. H. Mitchell; res., 360 Shaw St., Toronto, Ont.

DELANCIE, HARRY SHERWOOD, Salesman, Westinghouse Electric and Mfg. Co., 705 Land Title Bldg.; res., 3716 Locust St., Philadelphia, Pa.

EDWARDS, HARRY GRISWOLD, Foreman, Construction Department, General Electric Co., 1036 4th Ave., Louisville, Ky.

FOSS, WILLIAM E., Division Engineer, Metropolitan Water and Sewerage Board, 1 Ashburton Pl., Boston, Mass

GARRETSON, HARRY DOUGLAS, Electrical Engineer, Stevenson Machine Co.; res., 138 Lancaster Ave., Buffalo, N. Y.

GOLDENSTEIN, MAURICE M., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

GRAHAM, ROY CULLEN, Secretary and Treasurer, Meeker Light, Heat and Power Co., Meeker, Colo.

GRAHAM, WILL FRANCIS, Merriam, Kansas.

GRIFFIN, WILLIAM R. W., Rochester and Eastern Rapid Railway Co., Canandaigua, N. Y.

HANDLONG, GEORGE, Western Electric Co., 463 West St., New York City.

HEARN, GEORGE A., Electrical Engineer Vallejo, Benicia and Napa Railway Co., Napa, Cal.

HEIM, JOHN BAPTIST, Electrician U. S.S. Albany, U. S. Navy; res., 501 Georgia St., Vallejo, Cal.

HEMENWAY, THOMAS SHACKELFORD, Assistant Engineer, L. M. Erricsson Telephone Mfg. Co., Military Road; res., 369 Norwood Ave., Buffalo, N. Y

HIBBEN, FREDERICK MARTIN, Assistant Electrical Engineer, Cleveland Electric Illuminating Co., Wilbur Ave. S. E., Cleveland, O.

HORTON, ALBERT J., Engineer, Cutler-Hammer Mfg. Co., 79 E. 130th St., New York City.

IREDELL, GEORGE S., Electrical and Mechanical Engineer, Pendexter Bldg res., 203 W. 10th St., Austin, Texas.

JACKSON, E. LEROY, Keystone Electrical Instrument Co., 1229 Real Estate Trust Bldg., Philadelphia, Pa.; res., Hammonton, N. J.

JONES, CHARLES WILLIAM, Assistant Engineer of Construction, New York, New Haven and Hartford Railway Co.; res., 196 North St., Stamford, Conn.

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JONES, FRED B., Engineer, Utah Independent Telephone Co., 115 State St., Salt Lake City, Utah.

KITSEE, ISADOR, Research Work, 209 Walnut Pl., Philadelphia, Pa.

LEVINSON, ISAAC, Manager, Electrical Department, United Cigar Stores Co., 44 W. 18th St., New York City.

LEWIS, FRED SIGNOR, Superintendent Electric Plant, Cleveland Illuminating Co., 2190 E. 78th St., Cleveland Ohio.

LINDGREN, HENRY W., Draughtsman, Electrical Installation Co., Monadnock Bldg., Chicago; res., 515 N. 7th Ave., Maywood, Ill.

LONGINO, JAMES LELAND, in charge of sub-stations, Jamestown Exposition, Department of Electricity; res., 435 Duncan Ave., Norfolk. Va.

LUCKE, CHARLES EDWARD, Adjunct Professor Mechanical Engineering, Columbia University; res., 544 W. 142d St., New York City.

MAGID, LEWIS BORRIS, Development of Hydro-Electric Plants, Tallulah Lodge, Georgia.

MARSHALL, ALBERT JACKSON, Illuminating Engineer, Holophane Co., 227 Fulton St., New York City.

MONORI, EMIL, Electrical Engineer, General Electric Co.; res., 605 So. Centre St., Schenectady, N. Y.

MURPHY, FRED E., Erecting Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.

NORRIS, THOMAS FENDOL, Electrical Engineer, West Penn Railways Co., McKeesport, Pa.

NOYES, HILAND BATCHELLER, Chief Engineer, Omaha and Council Bluffs Street Railway Co., 2623 N. 20th St., Omaha, Neb.

OGDEN, KENNETH CHARLES, Agent, New York Edison Co.; res., 318 W. 57th St., New York City.

PENDRAY, EDWARD EVERETT, Assistant Professor Physics, Missouri State Normal School, Cape Girardeau, Mo.

PENNIE, JOHN C., Attorney at law; res., 83 Park St., Montclair, N. J.

REED, EMERSON G., Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg; res., 200 Franklin Ave., Wilkinsburg, Pa.

ROBINSON, R. E., Chief Inspector, Southern Bell Telephone and Telegraph Co., 77 Wentworth St., Charleston, S. C.

SEELIG, ALFRED E., Electrician, Electro Bleaching Gas Co., 24 E. 21st St.; res., 1236 Madison Ave., New York City.

SHAW, JOSEPH DUTY, Underground Engineer, Allegheny County Light Co. and Pittsburg Railways, Pittsburg, P.

SKINKLE, JAY WILLIAM, Cable Engineer, Western Electric Co.; res., 6562 Stewart Ave., Chicago, Ill.

STOCKING, FRED TOWNSEND, Assistant Electrical Engineer, Hydro-Electric Power Commission of Ontario, 710 Continental Lift Bldg., Toronto, Ont.

STRICKLAND, HENRY FREDERIC STEPHENSON, Chief Electrical Inspector, Canadian Fire Underwriters Association, 27 Wellington St. E., Toronto, Ont.

SYMONS, HAROLD DALRYMPLE, Engineer, British Westinghouse Electric and Mfg. Co.; res., 29 Alice Str. Sale near Manchester, England.

TADA, KOZO, Engineer, Kyoto Municipal Electric Works, Kyoto, Japan.

THAYER, WILLIAM CURTIS, Electrical Contractor, East Aurora, N. Y.

THORPE, CHARLES NEWBOLD, Manager, Franklin Electric Mfg. Co., 602 Fisher Bldg.; res., 2149 Kenmore Ave., Chicago, Ill.

UNDERWOOD, FREDERICK VIRGINIOUS, Superintendent, Electric Meter Department, Birmingham Railway Light and Power Co., 2100 1st Ave., Birmingham, Ala.

Total, 60.

Meeting of the Institute at New York, October 11, 1907

At the meeting of the Institute to be held in the Auditorium of the Engineers' Building, 33 West Thirty-ninth street, New York, October 11, 1907, Paul M.

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Lincoln, engineer of the power division, Westinghouse Electric & Manufacturing Company, will present a paper, printed in this issue of the PROCEEDINGS, on the "Grounded Neutral With and Without Series Resistance in High-Tension Systems." There will be presented at the same time, also printed herein, papers by F. G. Clark, superintendent of the power station of the Pennsylvania Tunnel and Terminal Railroad Company, and Geo. I. Rhodes, assistant engineer of the Interborough Rapid Tránsit Company, covering the results of actual operation in their systems with the neutral point grounded through series resistance. It is expected that there will be in addition a full discussion on the evening of the meeting.

As this subject is one of growing prominence, and as it is highly desirable to have as general an expression of opinion as possible, it is requested that all members having any experience with the grounded neutral will either be present and join in the discussion or send a written communication.

November Meeting of the Institute

The two hundred and twenty-second meeting of the Institute will be held in the Auditorium of the Engineers' Building, 33 West Thirty-ninth street, New York, on Friday, November 8, 1907, at 8:15 p.m. A. H. Armstrong, assistant engineer of the railway and traction department of the General Electric Company, Schenectady, will present a paper entitled, "Comparative Performance of Steam and Electric Locomotives."

Meeting of the A. S. M. E.

The first monthly meeting of the American Society of Mechanical Engineers is announced for October 8 at 7:45 p.m., in the Auditorium of the Engineers' Building, the subject of discussion being "Industrial Education."

Applications for Election

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the Secretary before November 8, 1907.

6684 L. P. Burgner, Toledo, O.
6685 H. S. Carr, West Duluth, Minn.
6686 D. F. Henderson, Spokane, Wash.
6687 W. W. Kinsley, Jr., Cleveland, O.
6688 A. J. Soper, Schenectady, N. Y.
6689 H. T. Kohlhaas, Brooklyn, N. Y.
6690 J. F. Strachan, San Francisco, Cal
6691 G. C. Donaldson, DuBois, Pa.
6692 John Gelzer, Jr., Birmingham, Ala.
6693 J. H. Priest, Manchester, N. H.
6694 C. R. Young, Bloomfield, N. J.
6695 A. D. Brinckerhoff, Springfield, Ill.
6696 I. Nakahara, Tokyo, Japan.
6697 J. E. Wickstrom, Seattle, Wash.
6698 J. L. Woodress, St. Louis, Mo.
6699 F. E. Geibel, Schenectady, N. Y.
6700 H. W. Evans, Chicago, Ill.
6701 L. L. Barnes, Atlanta, Ga.
6702 A. B. Thomson, New York City.
6703 R. B. Wainwright, New York City.
6704 W. H. Bass, Liberty, N. Y.
6705 E. A. Hultz, Chicago, Ill.
6706 Llewellyn Evans, Berkeley, Cal.
6707 C. A. Heinze, Los Angeles, Cal.
6708 W. R. Layre, Berkeley, Cal.
6709 R. R. Keely, Edmonton, Can.
6710 R. M. Wynn, Saulte Ste Marie, Ont.
6711 T. Bjorgerd, Seattle, Wash.
6712 P. MacL. Marshall, N. Y. City.
Total, 29.

Associates Transferred to the Grade of Member

The following Members were transferred from the grade of Associate by the Board of Directors at the meeting held July 26, 1907. This notice was inadvertently omitted from the August PROCEEDINGS.

J. F. NEWMAN, Superintendent and Chief Engineer, Wood Motor Vehicle Co., Chicago, Ill.

B. F. WOOD, Assistant Engineer, Motive Department, P.R.R., Altoona.

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RICHARD MCCULLOCH, Assistant General Manager, St. Louis Transit Co.

J. L. HARPER, Chief Engineer, Niagara Falls Hydraulic Power and Mfg. Co., Niagara Falls, N. Y.

A. R. CHEYNEY, Station Supt. Philadelphia Electric Co., Philadelphia, Pa.

W. W. BLUNT, British Westinghouse E. & M. Co., London, Eng.

CALVERT TOWNLEY, First Vice-president, Consolidated Ry. Co., New Haven.

A. W. K. BILLINGS, Havana, Cuba.

EDSON, OLIVER SESSIONS, Western Sales Engineer, Stanley G. I. Electric Mfg. Co., Chicago, Ill.

FRANK RICHARDS FORD, Consulting Engineer, 115 Broadway, New York City.

CHARLES HOLLAND MORITZ, G neral Superintendent Niagara Works, Aluminum Co. of America, Niagara Falls, N. Y.

REUBEN IRVING WRIGHT, Engineer, The Electric Controller & Supply Co., Cleveland, O.

DAVID HALL, Assistant Chief Engineer, The Bullock Electric Mfg. Co., 4816 Ash St., Station H, Cincinnati, O.

Applications for Transfer

Recommended for transfer by the Board of Examiners, September 20, 1907. Any objection to these transfers should be filed at once with the Secretary.

CLIFFORD WAYNE HUMPHREY, Consulting and Designing Engineer, The Rookery, Chicago, Ill.

ROBERT CARR LANPHIER, Secretary and Manager, Sangamo Electric Company Springfield, Ill.

ALBERT GUSTAV WESSLING, Assistant Engineer, Bullock Electric Manufacturing Company, Cincinnati, O.

WILLIAM NELSON SMITH, Electric Traction Engineer, Westinghouse, Church, Kerr & Company, New York.

CHARLES EZRA SCRIBNER, Chief Engineer, Western Electric Company, Chicago, Ill.

KEMPSTER B. MILLER, Consulting Electrical Engineer, 1454 Monadnock Block, Chicago, Ill.

Personal

MR. GEORGE F. JOHNSON of Cornell University, '07, is now in the test department of the General Electric Company, Schenectady, N. Y.

MR. RALPH D. NYE has been transferred by the Westinghouse Electric and Manufacturing Company from the East Pittsburg factory to the Cleveland sales office.

MR. CRELLIN CARTWRIGHT has been transferred from the foreign department of the General Electric Company in Schenectady, to the office of the company's representative in Japan, as engineer.

MR. W. S. STUBBS, formerly at Amsterdam, New York, has gone to Rio Janeiro, Brazil, where he expects to remain for eighteen months or more, in the interest of the General Electric Company.

MR. KENNETH L. CURTIS, formerly assistant professor of electrical engineering at Leland Stanford Jr. University, California, has taken a position with Westinghouse Church, Kerr and Company, of New York City.

MR. ELLERY B. PAINE has left the electrical engineering department of the North Carolina College of Agriculture and Mechanical Arts, to become assistant professor of electrical engineering at the University of Illinois.

MR. A. R. SWOBODA, for the past two years instructor in electrical engineering at the University of Nebraska, has resigned his position there, and is now in the engineering department of the Kellogg Switchboard and Supply Company, Chicago.

MR. EARL E. RANNEY has left the employ of the By-products Coke Corporation at South Chicago, Ill., to accept a position in the testing and erecting departments of The Electric Con-

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troller and Supply Company, Cleveland, Ohio.

MR. W. R. STINEMETZ has returned from a two years trip to Italy, having completed two single-phase railroads, and will be connected with some work being done by the Westinghouse company for the U. S. Government in Washington, D. C.

MR. C. H. McNARY has resigned his position as electrical engineer for the Folsom Development Company, to accept the appointment of vice-president and general manager of the Lewiston-Clarkston Company, with headquarters at Clarkston, Washington.

MR. A. R. DENNINGTON, formerly instructor in electrical engineering in charge of electrical laboratories at the Pennsylvania State College, is now assistant principal of the school of electrical engineering of the International Correspondence Schools, Scranton, Pa.

MR. CALVIN W. RICE, Secretary of the Amercian Society of Mechanical Engineers, has recently returned from the Continent of Europe with his wife, who was ordered abroad to take the waters at one of the German spas. Mrs. Rice has returned thoroughly restored in health.

MR. NORMAN C. MCPHERSON, until recently the chief engineer of the Duquesne Light Company, of Pittsburg, whose electric plant he designed and constructed last year, has joined the engineering staff of Westinghouse, Church, Kerr and Co., and is now located in New York.

MR. HARRY PICKHARDT has joined the sales department of the Holophane Company, and will be located with the Western department at Chicago, Mr. Pickhardt was heretofore engaged in electrical equipment work, but will devote his time in the future to the illuminating field.

MR. L. R. NASH, has given up the management of the Savannah Electric Company to return to the office of Stone and Webster, Boston, where he will be engaged for the present upon special problems in connection with the operation and management of their various companies.

MR. H. Y. HALL, JR., formerly with J. G. White and Co., and in charge of installation of five 60,000-volt substations for the Buffalo, Lockport and Rochester Railway Company, is now assistant electrical engineer for the Southern Pacific Company, at San Francisco, on power station and substation design.

MR. J. C. HUFFMAN has resigned from the position of electrical engineer of the Oneonta and Mohawk Valley Railroad, to take up sales work with the Canadian Westinghouse Company, Ltd., at the Winnipeg office. He will travel out of Calgary, covering the provinces of Alberta, Saskatchawan, and eastern British Columbia.

MR. E. W. DEAN leaves London this month for the Argentine Republic, S. A., where he has an appointment on the staff of the Buenós Ayres and Rosario Railway Company, Ltd., which is about to build a power station and lay down an extensive installation for the supply of electric current to the various yards, offices, and terminal stations.

MR. GEORGE J. HENRY, JR., made a recent trip East in the interest of the Pelton Water Wheel Company, to contract for a lot of machine work in order to relieve the congestion of the San Francisco shops during a period of threatened strike. Conditions have materially improved since then, however, and prospects for San Francisco are brighter.

MR. WALTER ATWOOD HALL, for the past decade identified with the Lynn works of the General Electric Company,

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and during the last two years engineer in charge of the transformer department, transferred his headquarters on September 1st, to the Pittsfield works of the same company. Mr. Hall will be associated with Mr. Walter S. Moody, engineer-in-charge, as assistant engineer of the enlarged department formed by the concentration at Pittsfield of the greater part of the company's transformer interests.

Obituary

MR. WILLIAM JOSHUA PHELPS died on September 3, at the Grace Hospital, Detroit, of inflammation of the brain, having undergone a mastoid operation on August 28. Mr. Phelps was born in Elmwood, Ill., Nov. 19, 1867. He was a graduate of Knox College, Galesburg, Ill., with degrees of A.B., and A.M. His first work was in connection with the mines of the Elmwood Coal Company, Elmwood, Ill. This involved making maps of all underground work to comply with a new law; installing an electrical pump and generating plant, on account of the unfavorable dip of tl e vein, the survey for the bore hole being made under rather difficult conditions, which at that period involved some original work. Later, he was retained by the city of Asheville, N. C., to examine and report on the street lighting system. In February, 1897, he began working on the incandescent electric lamps which have since become known under the trade name "Hylo." This work was recognized by a silver medal in 1900, from Paris, and by a report of the Franklin Institute in 1903. The commerical turn-down electric lamp is now regarded as a permanent and useful appliance in electric lighting. This arrangement so common now as to be standard, involved a great deal of study and experiment by Mr. Phelps before it became practicable; indeed it was due to his persistent experiment and causing of experiments by manufacturers at his expense that made possible the low candle-power filament of long life and good efficiency. Mr. Phelps was also the inventor of the Phelps motorless flasher, which has proven to be of great use in the electrical advertising field. He also did considerable useful work in thermopiles, thermostats, and resistance metals. Mr. Phelps was elected an Associate of the American Institute of Electrical Engineers, March 25, 1896.

Books Received

The following volumes have been received from the McGraw Publishing Company and placed in the Library of the Institute:

ELECTRIC TRANSMISSION OF WATER POWER. A descriptive treatise from the standpoint of the engineer and financier. By Alton D. Adams. Cloth. 335 pages, illustrated. New York, McGraw Publishing Co. Price $3 net.

CONTENTS.—Chapter I.—Water-power in Electrical Supply. II.—Utility of Water-power in Electrical Supply. III.—Cost of Conductors for Electric-power Transmission. IV.—Advantages of the Continuous and Alternating Current. V.—The Physical Limits of Electric-power Transmission. VI.—Development of Water-power for Electric Stations. VII.—The Location of Electric Water-power Stations. VIII.—Design of Electric Water-power Stations. IX.—Alternators for Electrical Transmission. X.—Transformers in Transmission Systems. XI.—Switches, Fuses, and Circuit-breakers. XII.—Regulation of Transmitted Power. XIII.—Guard Wires and Lightning Arresters. XIV.—Electrical Transmission under Land and Water. XV.—Materials for Line Conductors. XVI.—Voltage and Losses on Transmission Lines. XVII.—Selection of Transmission Circuits. XVIII.—Pole Lines for Power Transmission. XIX.—Entries for Electric Transmission Lines. XX.—Insulator Pins. XXI.—Insulators for Transmission Lines. XXII.—Design of Insulator Pins for Transmission Lines. XXIII.—Steel Towers.

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Baltimore.........Dec. 16, '04	J. B. Whitehead.	C. G. Edwards.	2d Friday.
Boston............Feb. 13, '03	H. E. Clifford.	C. H. Porter.	3d Wednesday
Chicago..................1893	P. B. Woodworth.	H. R. King.	1st Tuesday after N. Y. meeting.
Cincinnati.........Dec. 17, '02	G. A. Wessling.	A. C. Lanier.	
Columbus.........Dec. 20, '03	R. J. Feather.	H. L. Backman.	1st Monday.
Ithaca............Oct. 15, '02	E. L. Nichols.	H. H. Norris.	1st Friday after N. Y. meeting.
Minnesota..........Apr. 7, '02	H. J. Gille.	Barry Dibble.	2d Monday after N. Y. meeting.
Pittsburg..........Oct. 13, '02	H. W. Fisher.	H. D. James.	2d Tuesday.
Pittsfield..........Mar. 25, '04	J. Insull.	H. L. Smith.	3d Thursday.
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San Francisco......Dec. 23, '04	C. L. Cory.	A. H. Babcock.	
Schenectady.......Jan. 26, '03	D. B. Rushmore.	W. C. Andrews.	2d Wednesday.
Seattle............Jan. 19, '04	C. E. Magnusson.	W. S. Wheeler.	3d Saturday.
St. Louis..........Jan. 14, '03	A. S. Langsdorf.	J. H. Finney.	2d Wednesday.
Toledo............ June 3, '07	W. G. Nagel.	Geo. E. Kirk.	
Toronto..........Sept. 30, '03	R. G. Black.	L. W. Pratt.	2d Friday.
Urbana...........Nov. 25, '02	Morgan Brooks.	M. K. Akers.	1st Wednesday
Washington, D. C..Apr. 9, '03.	P. G. Burton.	Philander Betts.	1st Thursday.
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Purdue University..Jan. 26, '03	C. P. Matthews.	J. W. Esterline.	Every Tuesday.
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OF THE

American Institute

OF

Electrical Engineers.

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Standards Committee—Engineering Data, and Symbols.

THE new Standards Committee has under consideration the preparation of supplements for the recently adopted Standardization Rules in order that the rules and their appendices may be made of more use and value to engineers in general.

It is believed that there is much engineering data which are not now conveniently accessible, which may be made readily available if published in connection with the Standardization Rules. Many of the Institute papers which have been presented in the past have contained data, often in tabular form, which will be much more useful if collected in the manner proposed On the other hand, there are new and special subjects which are continually coming to the front in the practice of the engineering profession, and the data of which have not found a place in ordinary text-books and handbooks, but which would be acceptable in the collection which could be made by the Standards Committee. Members may have at hand, curves, short methods, empirical formulas, and special data which may be of considerable value, but not of sufficient magnitude or importance to be presented in an Institute paper. The proposed method will be well adapted for these data.

This is a matter upon which the committee must have the coöperation of the membership at large. If it receives such coöperation it can probably accomplish useful results. If, however, no move is made upon the part of the members to coöperate in this matter, the committee may conclude that the lack of interest indicates that the matter is not of sufficient importance to justify much effort on its part.

The Standards Committee is also considering the utility of bringing together symbols ordinarily used in text-books, in the technical press by engineers, manufacturers, contractors, and others, and by the Patent Office, in order to make these symbols available, and to do what may be found practicable and expedient in systematizing and standardizing these symbols. Assistance from the members is requested.

Comment, suggestions, and assistance along the lines above indicated will be acceptable to the committee, and may be addressed to the secretary of the Institute for the attention of the Standards Committee.

Annual Convention Papers.

THE number of papers offered at the annual convention of the Institute is growing rapidly from year to year. As a consequence the editing and printing of the advance copies is becoming more and more difficult, as most of the manuscripts are not submitted until a

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very late date. This condition is not only unfair to the editing staff, but also defeats one of the main objects of the advance copies—to give opportunity for consideration of the papers in advance of the convention.

The Meetings and Papers Committee is considering the advisability of setting some date in April after which it may refuse to receive manuscripts for the convention. Any person contemplating the presentation of a paper at the convention should take note of this and assist the committee and the editorial staff by preparing and submitting his manuscript during the winter months.

University of Illinois.

THE New York meeting of November 8 was enlivened by the attendance of a party of engineering students from the University of Illinois, ciceroned by Professor Morgan Brooks. The visit to New York was so timed that three days were spent in the city, and many interesting engineering undertakings were inspected, some of them finished and in operation, while others were in process of construction. These prospective young engineers were therefore enabled to appreciate the importance of their future work, and the nature of the responsibilities to be incurred. The entire tour was calculated to cover as many branches of engineering as possible, and there can be little doubt of its permanent advantage. It is practically impossible to estimate this value in dollars and cents, which is supposed to be the standard that should be used. Each one of the party has, however, received impressions which will form a most interesting feature of his future store of recollections, which will remain his personal and individual possession throughout his active life. Among the more interesting features of the trip following immediately after the stay in New York, was the sea voyage by the Old Dominion line to Norfolk, and a reception by President Roosevelt at the White House.

Coming Meetings.

Meeting of the Institute at New York, December 13. 1907.

THE two hundred and twenty-third meeting of the Institute will be held in the auditorium of the Engineers' Building on Friday, December 13, 1907, at 8:15 p.m. The duplex stoker boiler, with the results of a test, will be described by Mr. Walter S. Finlay, of the Interborough Rapid Transit Company, With this apparatus a greatly increased output can be obtained from a boiler. Other papers relating to the steam engineering side of a modern power plant will also be presented at this meeting.

At the meeting on January 10th there will be papers on single-phase distribution, by W. S. Murray, electrical engineer of N. Y., N. H. and H. R.R., and by Gerard B. Werner of New York; also a paper on "A New Single-phase Railway Motor," by Ernst Alexanderson, Electrical Engineer, General Electric Co., Schenectady.

Illuminating Engineering Society.

THE next meeting of the New York Section of the Illuminating Engineering Society will be held at the Engineers' Building, 33 West Thirty-ninth street, New York, on Thursday evening, December 12, 1907. A paper entitled "The Relation of Architectural Principles to Illuminating Engineering Practice" will be presented by Mr. Bassett Jones, Jr.

Pittsfield Section

THE meeting of December 5 is expected to be devoted to the preservation of forests, with particular attention to its beneficial influence on the supply of water power for the generation of electricity. Mr. William Stanley of Great Barrington has been invited to address the Section on December 20. Early in 1908 a social meeting will probably be held. Members in Western Massachusetts should endeavor to attend some of these meetings.

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Apprenticeship Course at the Bullock Electric Manufacturing Company.*

During the senior year much was done to impress upon the students the desirability of an apprenticeship course. The professors recommended it, the technical press, and especially the representatives of the manufacturing companies urged it. After some consideration, for certain peculiar reasons I decided to take the course as offered by the Allis-Chalmers Company at their Cincinnati plant.

My application was accepted, and I left Worcester Wednesday, June 27, 1906 for Cincinnati. I arrived there the next day about 2 p.m. and knowing that the company's plant was not located in the city, I put up at a hotel. It was at this hotel I made my first acquaintance with Cincinnati water. It is said that in Cincinnati everybody drinks beer.

That evening I took a trolley ride out to Norwood to locate the shops. It was a fine ride, taking one from Fountain Square, the business center of the city, up the Mount Adams incline through Eden Park and a very fine residential district beyond, the end of the line being about 40 minutes' ride from the city.

I might say in passing that many of the inclines in Cincinnati are so steep that the cars have to be drawn up by means of cables. From any of these inclines a magnificent view of the city can be obtained. From this particular one you are not only able to obtain a fine view of the city but can see up and down the river with its four bridges crossing over into Covington and Newport, Kentucky. Last winter this place was the vantage point where thousands watched, during the floods, that fascinating yellow torrent of water that carried destruction with it. Here also are located the famous Rockwood pottery plant and the Cincinnati art museum.

I had arrived at the end of the line without seeing the shops, but on the return trip the car ran for a short distance on another track, and in passing a very large building of buff-colored brick, I looked out and saw high up on the wall " Bullock ". I could not but express my surprise at the appearance of the buildings and their surroundings. It was an agreeable surprise.

The next morning I returned to Norwood and saw Mr. A. C. Wessling who has charge of the apprentices. In the employment office I obtained a map of the town and then started out to find room and board. I found it quite difficult to get a room, but after about three hours I found a very pleasant one with a German family. My room was located about ten minutes' walk from the shop and about five minutes' from the boarding house. The rates were very reasonable, $2.00 a week for a room and $3.50 a week for board.

The Bullock plant is located at the junction of two railroads, the Baltimore & Ohio and the Cincinnati, Lebanon & Northern. There are about eight buildings known as shops No. 1, No. 2 and No. 3, the service buildings, administration building, pattern shop, foundry, and Klondike, besides several small outlying buildings. Klondike is a storage building away in the rear and devoid of heat.

I started to work Monday morning, July 2 in the controller department. The departments that comprise the apprenticeship course are as follows:

The controller, the commutator, the winding, assembly No. 1 and No. 2, bill of material, test, sales, and engineering. The course, however, followed no rigid plan and probably no two students would have the same course. Some departments you would never be in at all, and once you reached the test you would stay there an indeterminate length of time. Vacancies in the sales department were filled by men from the testing department.

*A paper read at a meeting of the Worcester Polytechnic Institute Branch, October 29, 1907.

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From 12 to 18 weeks was the usual time spent in each department. I spent the first 12 weeks in the controller department. Here they build controllers and potential starters and also do their detail work.

From the controller department I went to the winding department where I stayed 20 weeks, this time being used in doing different kinds of work. I wound vertical induction motors until I was tired of them, and every time I see one now it makes me think of the first one I wound. From the winding department I went to assembly No. 1 where they assemble, for test, machines of about 200 kw. and less. Here I stayed 12 weeks, the first four as a helper, and the greater part of the remaining time I had a helper. The work in the assembly often made me think of a load-curve on some power plants, the peak coming on about four o'clock in the afternoon, oftentimes resulting in a not unwelcome overtime pass, while at other periods we would move around or chip away at pedestals in order to look busy.

The remainder of the time I was with the company was spent in the testing department on the night shift. While the night time is not favorable for doing good work, I think I obtained more experience than I would on the day shift an equal length of time. Anyway the pay-slip was heavier.

There was, as a rule, except in the test, never more than two or three students in the same department at the same time. At the time I entered the employ of the company there were about 25 of us. When I left there were about 12 or 15.

The students were from all parts of the country—North, South, East, and West. There being so few of us we became well acquainted, and our club meetings were as a rule very pleasant affairs. We discussed all topics at our meetings, nearly everyone giving at first his thesis in abstract. We also had at various intervals talks by different men of the engineering department. The engineers seemed always willing to address the students at their meetings, and also to answer any questions when in the shops.

In general the attitude of the men in the shops was to assist rather than hinder the student. Many tried, of course, to give the students the heaviest and dirtiest work, but if the student did his share this was the exception rather than the rule.

Taken as a whole, therefore, I can say that my year with the Allis-Chalmers Company was agreeably and profitably spent.

Sections and Branches

Armour Institute of Technology Branch

The meeting of October 24 was called to order at 7:40 p.m. with Mr. T. C. Oehne Jr. presiding. After the usual routine business, Mr. Souther read the report of the committee on furnishing the new A.I.E.E. rooms in Chapin Hall, and an assessment was levied on each member for that purpose. The time of meeting was changed to the first and third Thursdays of every month to avoid conflicting with the Civil Engineering Society. At the suggestion of Mr. Nichols, a committee was appointed to arrange for a banquet to promote better acquaintance between the juniors and seniors of the Branch.

Mr. Souther then read his paper on, the " Selection of a Proper System for an Electric Railway ". This paper dealt particularly with the electrification of the Rock Island between the Chicago terminal and Blue Island. The paper opened with an outline of the systems in use on various electrified roads. Some of the main points taken up were: motor-cars versus locomotives; effect of schedule upon selection of motors; phase, voltage, and distribution of alternating-current and direct-current systems. Then followed elimination exercises due to existing conditions assumed. It was decided to adopt

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high-tension direct-current locomotives for present equipment, to be gradually replaced by motor-cars suitable for multiple-unit control on a third-rail system.

After reading the paper, Mr. Jacobson gave Westinghouse estimates on the relative initial cost of direct-current and three-phase alternating-current installations.

Mr. Simpson spoke of the difficulty in locating the third-rail because of the small amount of clearance between the track and the webs used on street viaducts.

Professor Radtke gave some of the points of superiority in both alternating-current and direct-current systems, and explained the skin-effect found in the third-rails carrying an alternating current.

The meeting of October 31 was called to order at 7:45 p.m., vice-chairman T. C. Oehne, Jr. presiding.

Mr. Nichols presented a paper on "Equipment and Operation of Direct-Current and Alternating Current Sub-stations of the Commonwealth Edison Co."

Mr. Nichols first took up the general considerations governing the location of sub-stations and the methods of distributing power in alternating-current and direct-current districts. A general description of the apparatus was given and a comparison drawn between different types, especially between the vertical and horizontal types of motor-generators. The paper gave a detailed description of the arrangement of the equipment of a typical sub-station with the operation of its storage-battery adjunct.

Mr. Nichols concluded by giving methods of starting motor-generators and synchronous converters, explaining some of the types of regulators used.

A lively discussion followed, and many interesting and valuable points were brought out by questions on the paper. The author explained by diagrams, portions of the sub-station wiring for special apparatus. The subject of the storage-batteries in their relation to sub-station work was discussed. Mr. Nichols gave diagrams of several safety devices.

A vote of thanks was given the author for the excellent manner in which he treated his subject.

University of Arkansas Branch

A meeting of this Branch was held October 14, M. F. Thompson presiding, with a total attendance of 14. M. F. Thompson was elected president, and C. R. Rhodes secretary, for the year. Meetings will be held on the first and third Mondays of every month.

The meeting of October 21, Mr. Thompson presiding, had an attendance of 12. An Institute paper on "Standardization of Fuses," was read by C. R. Rhodes, and discussed by the members.

Baltimore Section

A meeting of this Section was held October 11, at Johns Hopkins University, J. B. Whitehead presiding, with a total attendance of 16. This meeting being the first of the season 1907-08, was largely devoted to a discussion of the plans and program for the year. The report of Mr. Charles G. Edwards, the delegate to the annual convention at Niagara Falls, was read and adopted. The papers of the current New York meeting were discussed. R. W. Wood, Professor of experimental physics, Johns Hopkins University, read a paper on the "Possibilities of the Substitution of an Alloy of Metals for Copper."

Boston Section

At the regular meeting of the Boston Section of the American Institute of Electrical Engineers held on October 16, 1907, the annual election of officers took place with the following results:

William L. Puffer, chairman;

A. E. Kennelly, vice-chairman;

C. H. Tapping, secretary and treasurer.

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Executive committee:
J. W. Corning,
G. S. Gibbs,
G. C. Shaad,
I. F. Vaughan,
J. B. Wiard.

The diversity of electrical concerns represented above will probably suggest that the nominating committee gave some thought to their task. The results, it is hoped, will speak for themselves.

This executive committee held a meeting on Friday evening, Oct. 25, with all of the members present but one. It is the purpose of this committee to meet once a month at least, on the Friday immediately following the regular monthly meeting of the Boston Section.

At the meeting on Friday, Oct. 25, arrangements were completed for the meeting of Nov. 20, and arrangements are under way for the meeting of Dec. 18. It is the purpose of each member of this committee to have present at each meeting some men well posted on the subject of the paper to be presented, for the purpose of discussion.

We have in mind the idea of alternating—one month an original local paper, the next month an abstract of the most recent paper presented at the New York meeting.

The matter of changing the date for the annual election is to be put before the Section on Nov. 20.

Cincinnati Section

A regular meeting of this Section was held at the Grand Hotel, October 24. An address was delivered by Chas. E. Lord, patent attorney, and manager of the patent department of the Bullock Electric Manufacturing Company, entitled: "The Electrical Engineer-Inventor: Some of the Patent Pitfalls which Beset Him".

Cleveland Section

The credit for starting the movement to organize the Cleveland Section is due primarily to Messrs. H. B. Dates and C. W. Ricker, who about September 1, 1907, communicated with nine other Cleveland members, with reference to a petition to the Institute to form a Section. This petition was forwarded to the Board of Directors on September 25, the original signers being Messrs. H. B. Dates, C. W. Ricker, Geo. B. Dusinberre, F. F. Rossman, E. P. Roberts, Bret Harter, C. E. F. Ahlm, C. E. Reid, and J. C. Lincoln.

Permission to organize being obtained, a call signed by the above was sent to the Members and Associates in Cleveland and its vicinity on October 23, to meet on the evening of October 28, at the electrical engineering building of the Case School of Applied Science. Fifty-one Members and Associates and two interested outsiders responded. Professor Dates took charge of the meeting and A. M. Allen was appointed temporary chairman. After giving a short history of the movement, Mr. Allen appointed as a committee to frame a set of by-laws, Messrs. Ricker, Dates, Ballard, Kent, and Harter.

Paul Spencer, of Philadelphia, chairman of the Sections Committee was then introduced and gave a very interesting and instructive talk on the general outline and policy of local organizations, laying special stress on the fertile field in Cleveland and its vicinity for a thriving Section, and the desire of the Institute to enlist the interest of young technical men, quite a number of whom were present from the Case school.

The report of the committee on by-laws was accepted after much discussion, the question of admission of non-Institute members being left to a subsequent meeting. The time of regular meeting shall be the third Monday in every month, at 8 p.m. The place, the electrical engineering building of the Case School of Applied Science. The use of this building was very kindly donated by Professor Dates.

The by-laws being adopted, the following were elected: president H. B.

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Dates; secretary and treasurer F. M. Hibben; managers C. W. Ricker, A. C. Eastwood, and C. E. F. Ahlm; the above constituting an executive board for management.

President Dates taking the chair, after a few words appointed as a committee on non-Institute membership, Messrs. Dusinberre, Wallau, and Steiner. After a vote of thanks to Mr. Spencer for his trouble in coming on from Philadelphia, and to Professor Dates for the use of the building, there being no further business, the meeting adjourned.

The executive committee met on November 4 and appointed the following committees: meetings and papers committee; C. W. Ricker, J. C. Lincoln, R. I. Wright, H. L. Wallau, S. E. Doane, C. E. Reid, and J. R. Wilson. Committee on finance: E. P. Roberts, A. F. Adams, and A. M. Allen. The question of an informal dinner before each meeting was favorably discussed. Action will be taken at the next regular meeting.

In general the Cleveland Section feels greatly encouraged by the large number of charter members and the prospects for a thriving organization.

Cornell University Branch

The regular meeting of the Cornell University Branch was held in the Sibley library on Friday, Nov. 1, Chairman E. L. Nichols presiding. A letter from the A.I.E.E. committee on forest preservation was read. A special committee to select the proper evening for meetings was authorized, and the local membership committee was increased to eight members (two from each class) in addition to the chairman. A special committee was organized to audit the treasurer's accounts for the preceding year.

The program consisted in the presentation of abstracts of the New York papers of Oct. 11 as follows:

" The Grounded Neutral, with and without Series Resistance, in High-Tension Systems ", by P. M. Lincoln, abstract by J. E. Thomas.

" Experience with a Grounded Neutral on the High-Tension System of the Interborough Rapid Transit Co. ", by G. I. Rhodes, abstract by H. W. Smith.

" Experience with the Grounded Neutral ", by F. G. Clark, abstract by D. H. Braymer.

The presentation of the abstracts was followed by a discussion upon a number of practical aspects of the problem.

The work of the local Branch has been carefully organized for the coming year with committees on programs, membership, and entertainment. All of these committees are actively at work. The membership committee has already enrolled nearly one hundred students, who with the local membership form a Branch nearly as large as that at the end of last year The Branch occupies a distinct place among the student organizations and performs a most useful function. The membership committee has issued a small folder, a copy of which may be obtained from the secretary. The program committee has definite dates arranged for some time in advance, with tentative plans for the entire year. The entertainment committee will have at its disposal the proceeds of the local assessment of $1.00 per member, which will enable them to provide simple refreshments when necessary. A special form of receipt for the local dues has been prepared.

Minnesota Section

The Minnesota Section met October 28, 1907, at the offices of the St. Paul Gas Light Co., Henry J. Gille presiding.

Truman Hibbard of the Electric Machinery Co. abstracted the Niagara Falls paper by A. H. Armstrong on " Single-phase versus Three-phase Generation for Single-Phase Railways ". In commenting upon the paper, Mr. Hibbard stated that a three-phase generator should be able to give an output of 75 to 80 per cent. of its three-phase rating when operated single phase. He also stated that in nearly every case three-phase generators should

be installed, inasmuch as a three-phase machine would cost only one or two per cent. more than a single-phase machine wound on the same frame and of 75 per cent. of the three-phase rating.

W. T. Ryan abstracted the recent Institute papers on "The Grounded Neutral", after which J. C. Vincent explained the installation of the Twin City Rapid Transit Co. consisting of a three-phase transformer connected Y on the high-tension side (13,000 volts) and Δ on the low-tension side. The neutral point of the Y was then grounded through a six-ohm resistance. Three-phase relays were installed on each feeder.

Seventeen members and ten visitors were present.

University of Missouri Branch

This Branch held a meeting November 1, at Columbia, Mo., H. B. Shaw presiding, with an attendance of 17. The subject of the evening was the Institute papers on "The Grounded Neutral".

Pittsburgh Section

This Section held a meeting November 6, at the lecture hall of the Carnegie Institute. P. M. Lincoln presented an abstract of his original paper on "The Grounded Neutral", which was afterward discussed by R. P. Jackson, from a protection standpoint; by E. B. Tuttle, from the telephone company's standpoint; and by W. E. Moore, from an operating standpoint. Preceding the meeting, members and friends met for an informal dinner in the Nixon Grill.

Pittsfield Section

The Pittsfield section of the American Institute of Electrical Engineers was organized three years ago with a membership of approximately twenty. Its meetings since that time, held at regular intervals during the winter months, have proved of much benefit to those who have been able to attend.

The management this year believe it advisable to broaden the scope of the organization so as to make it possible for all who are in any way interested in engineering work to share its benefits.

It has therefore been decided to provide three classes of membership as follows:

"Regular"—including Members and Associates of the Institute. No charge will be made to this class of members.

"Local"—To include all others except Students who wish to associate themselves with the local Section and yet are not regular members of the Institute. Yearly dues $1.50.

"Student"—This class, as the name indicates, provides for students who are interested in engineering work. Yearly dues are $1.

The management is already in correspondence with a number of out-of-town men who are high up in their respective lines and is endeavoring to provide a series of meetings which no one can afford to miss. In addition to purely technical meetings, it is also intended to introduce occasional meetings of a more social nature, which will enable the members to become better acquainted.

Applications for membership may be handed to any member of the committee.

Membership Committee: H. W. Tobey, chairman, I. P. Thompson, H. L. Barnholit, C. R. Blakely, W. S. Williams, A. W. Townsley, W. M. Ackerman.

The first meeting was held in the Wendell Hotel parlor on Saturday, November 2, '07, at 8:15 p.m. The speaker for the evening, Mr. D. B. Rushmore, Engineer Power & Mining Department, General Electric Co., Schenectady. Mr. Rushmore was the founder of the local Section, therefore it was particularly appropriate that he should address the opening meeting of the year.

The second meeting was held Thursday, November 14, and was addressed by Mr. H. H. Barnes, Jr. Mr. William Stanley has promised to address the Section at an early date.

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Purdue University Branch

This Branch held a meeting October 22, at the Electrical Building, Purdue University, Mr. Webb presiding, with a total attendance of 48. The subject was "The Apprenticeship Course of the Westinghouse Electric and Manufacturing Company; discussed by Messrs. Benbow and Flanigan.

Toledo Section

The November meeting of the Toledo Section of the American Institute of Electrical Engineers, held Saturday evening, Nov. 2, 1907, at the Y.M.C.A. Auditorium, with an attendance approaching 200, notwithstanding the night was gloomy and threatening rain, is a testimony to the high quality of the speaker obtained for this, the sixth meeting of the Section.

The Section feels most grateful to Royal D. Tomlinson, a non-member, for the prestige thus extended to this new Section by his kindly granting the request made of him by the Secretary, Geo. E. Kirk.

Beginning the address by explaining views of the 96th St. power station, New York City, which was the first large alternating-current installation, besides the exterior, floor plans and sections were exhibited on the screen that the positions of the boilers, coal storage, ash disposal, and engines might be made clear.

Many pictures of plants under construction brought out details of the machinery as well as methods adopted in assembling the apparatus.

Among the problems to be solved at one of the New York stations of which Mr. Tomlinson formerly had charge, was the provision of a lubricating system having ample filtration capacity. This was worked out by permitting the oil filtering from the sacks to flow into either of two compartments which were connected in series with several other divisions in such a manner that oil passed upward and downward. The exhaust from the circulation pump heated the oil to aid in precipitation, thus automatically supplying the heating coils according to the oil circulated. For cleaning, the compartments were so arranged that the flow might bypass any compartment.

As to the horizontal vertical Manhattan type of compound engine, several views were shown, especially with the crank-pin 18-in. in diameter and 18 in. long upon which the two piston rods operate. Furthermore, the rotor of the generator serves as engine flywheel.

In considering exhaust-pipe design, emphasis was given to designing with ample capacity owing to the great rapidity with which the volume of steam increases at low pressures. Illustrative of the importance of this detail, tests of losses and how they are overcome were gone into.

The subject of turbines was given attention, views of installations of Curtis, Westinghouse, and Allis-Chalmers machines being shown. Sectional views of the latter two turbines were given, showing the disposal of balance pistons. In the Westinghouse machine these large disks are all at the high-pressure end, while in the Allis-Chalmers turbine the balance piston for the last stage is at the exhaust end, not only producing a more compact construction but simplifying the design of pressure pistons as to temperature differences.

Detail views were given showing the manner of attaching the blading of the Westinghouse turbine to the cylinder and rotor, and the manner of holding the outer ends of blades, while the calking of blading sections having outer ends locked in baffle strip or channel as used in Allis-Chalmers was fully shown.

That gas engines are entering power-stations in the shape of units of large size was indicated by views of several plants. Several pictures of a California station having a large gas engine, were thrown on the screen. The Nurnberg engine in German plants the large Allis-Chalmers gas engine at McKeesport, Pa., plant of the National

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Tube Co., and another at the Illinois Steel Co., Chicago, in course of erection, were shown. Some of these units have a rating upward of 5,000 horse power.

In closing, a view of the mammoth West Allis works of the Allis-Chalmers Co. was thrown upon the screen, the conception of which great undertaking, as well as many successes in fearlessly undertaking numerous difficult problems, especially in design of large steam engines, was attributed to the veteran engineer, Mr. Edwin Reynolds.

Mr. R. D. Tomlinson is supervising operating engineer of Allis-Chalmers Co., mechanical engineer in charge of the condenser department, Allis-Chalmers Co.; was formerly chief operating engineer of the Interborough Rapid Transit Co., New York City; and was, in 1905, President of the National Association of Stationary Engineers.

Urbana Section

The regular monthly meeting was held Oct. 16, at 7 p.m. in the Electrical Engineering Building of the University of Illinois. The lecture room was lighted by five tungsten lamps using about 200 watts in all. The usual illumination of this room is by fifteen carbon lamps that consume about 840 watts.

The papers presented at the last New York meeting were read and a general discussion followed. Professor Brooks illustrated by model some effects which may be produced by grounding an alternating-current circuit through resistance and through inductance.

Mr. Armstrong stated that the Illinois traction system operated without grounded neutral. He told of experiences that lead him to believe the resistance of earthed plates was so great that the addition of a small series resistance had little effect. Mr. Doyle related some interesting experiences with grounds on a high-potential long-distance circuit in California.

Seattle Section

The Institute members and their friends from Seattle, Spokane, and Electron, Washington, and Butte, Mont., assembled at the Spokane Hotel, Saturday, June 15, 1907 at 11 a.m. An hour was spent in getting better acquainted and then all repaired to the Silver Grill for luncheon. After luncheon a trip was taken to Liberty Park and the frequency-changing station of the Spokane and Inland Railway system.

Four 1000-kw. units are required here. Each consists of three separate machines, all mounted on the same base plate with flange couplings between adjacent rotating elements.

The single-phase, 2200-volt generators (25 cycle revolving field) are coupled at one end to a 1000-h.p. three-phase 60-cycle, 4000-volt 500 rev. per min. induction motor.

A 750-h.p., shunt-wound, 550-volt, direct-current machine is coupled on at the other end. This acts as a load balance for the induction motor, and thus makes a desirable load on account of the peaks being almost entirely eliminated.

The direct-current machine charges and discharges a storage-battery through a booster system, and is the first system of the sort applied to alternating-current railroading.

From here the party was escorted to various sub-stations, repair shops, etc., in Spokane.

After dinner a meeting was held in the new office building of the Washington Water Power Co., at which 15 members and 5 visitors were present.

A vote of thanks was extended the Spokane members for their successful efforts in entertaining the visitors.

The next morning a trip was taken over the Spokane and Inland single-phase system of railways to Waverly, where one of the transformer stations was inspected. This is the entrance to the Palouse wheat country.

Upon our return we were entertained by the Spokane members at the Spokane Club, and in turn we enjoyed their presence at lunch in the Silver Grill.

In the afternoon a trip was taken to Post Falls, Idaho, over the Coeur d'

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Alene and Spokane Electric Railway, to view the largest bear trap dam in the world, and to see the large power plant of the Washington Water Power Co. at that location.

The single-phase system of the Spokane and Inland Railway consists of about 125 miles of track, requiring eleven transformer stations. A 45,000-volt single-phase transmission line parallels the track separate from the trolley structure.

The trolley construction is of standard single catenary, single-arm type, for a working potential of 6,600 volts. The construction is excellent.

The electrical equipment for each motor passenger car consists of four 100-h.p. single-phase motors, complete with both alternating-current and direct-current multiple-unit pneumatic, control and one auto-transformer of the oil-insulated, self-cooling type.

The trolleys for alternating-current service are of the pneumatically operated pantagraph type. Wheel trolleys with base insulated for 6600 volts are also supplied.

The cars run under a 500-volt direct-current trolley in Spokane and a 6,600-volt alternating-current trolley outside of the city limits.

Six 50-ton locomotives, each equipped with four 150-h.p. single-phase motors are supplied for freight service.

Out-of-town members left Spokane Sunday evening and Monday after spending a couple of very enjoyable days due to the courtesy of the Spokane members.

Syracuse University Branch

The second October meeting was held Thursday evening, October 24, 1907. Seventeen members and sixteen visitors were present. The students of the University and the local members of the Institute are taking a very active interest in the work of the Branch. The discussion at this meeting was on the Institute papers, " The Grounded Neutral ". R. E. Allen, '08, abstracted the papers and led the discussion. Messrs. Graham, Bond, Blakeslee, Brown, Mason, Strong, Mott, and Myers took part in the discussion.

On the evening of November 7, 1907, H. J. Blakeslee read a paper on " The Work of the Bureau of Gas and Electricity of the City of Syracuse ". Mr. Blakeslee is superintendent of this bureau. The bureau was organized to carry out the provisions of the Hammond Bill, passed by the last Legislature. This bill provides for the supervision of the gas and electric service in Syracuse by an official of the city appointed for that purpose.

In spite of a severe storm which prevailed, the attendance at this meeting was twenty-eight.

Washington University Branch

A meeting of this Branch was held October 17, W. A. Burnet presiding, with a total attendance of ten. Professor Langsdorf, Mr. Wirdler, and Mr. Glauber were appointed to draw up by-laws. Mr. Burnet was elected chairman; Mr. Glauber, vice-chairman, and Mr. Beatty was elected secretary-treasurer.

A meeting held October 23, at Washington University, W. A. Burnet presiding, had a total attendance of 13. The by-laws were read and adopted; after which the meeting was devoted to a discussion of the oscillograph.

By-laws Washington University Branch American Institute of Electrical Engineers

I. *Name*

Under the Constitution of the American Institute of Electrical Engineers, and pursuant to authorization of its Board of Directors February 26, 1904, this Washington University Branch of the American Institute of Electrical Engineers is organized.

II. *Officers*

The officers of this Branch shall be a chairman, vice-chairman, and secre-

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tary-treasurer. These officers shall constitute an executive committee whose duties shall include the preparation of programs or meetings.

1. Election of officers. The members of the Branch shall vote by ballot for the three officers above named.

2. Term of office. The chairman and vice-chairman shall be elected at the last regular meeting in the month of May, and shall hold office for the following academic year. The secretary-treasurer shall be elected at the first regular fall meeting, and shall hold office for one year.

3. The executive committee shall meet whenever called by the chairman.

III. *Meetings*

The Branch shall meet on the afternoons of the second and fourth Wednesday of each month during the academic year, holiday periods excepted. Special meetings may be held at the call of the chairman or of any five members. The place of meeting shall be Room 202, Cupples Hall No. 2, unless otherwise specified.

IV. *Quorum*

Seven members shall constitute a quorum for the transaction of business.

V. *Dues*

Membership dues shall be ten cents per month. Special assessments may be levied by a majority vote of those present at any regular meeting.

VI. *Government*

In deciding questions of government of the Branch and procedure therein, the Constitution of the Institute the By-laws of the Institute, the By-laws of this Branch, and Roberts' Rules of Order shall be followed in the order named.

VII. *Amendments*

These By-laws may be amended by a majority of the members present at any regular meeting held after notice has been given that the amendment is to be considered.

UNIVERSITY OF WISCONSIN BRANCH

This Branch met October 24, at the City Library Building, F. M. Conlee presiding, with a total attendance of 45. Professor O. H. Ensign was elected chairman for the coming year, and Professor J. W. Shuster was re-elected secretary. A committee consisting of Messrs. M. C. Beebe, Frank Culver, and K. O. Burrer, was appointed to secure a permanent place of meeting large enough to accommodate the Branch. The New York papers on "The Grounded Neutral" were abstracted by K. O. Burrer, and discussed by the members. An original paper was given by Professor O. H. Ensign on the electric developments of Southern California, treating the subject historically, and with respect to its influence on the development of the locality. The attendance and interest shown were gratifying to all. Meetings for attendance of city members will be held the fourth Thursday of every month in the auditorium of the City Library. Weekly meetings are held at the University for the benefit of the student members.

WORCESTER POLYTECHNIC INSTITUTE BRANCH

There were thirty-eight in attendance at the second regular meeting of the Worcester Polytechnic Institute Branch on October 25, 1907. The meeting was devoted to a continuation of the "Summer Experiences" and also to accounts of the recent street railway convention and the Institute convention last June.

H. O. Lewis, P.G., who was in attendance at the Atlantic City convention, spoke briefly of the several papers presented and told of the exhibits and social features. Professor A. S. Richey supplemented Mr. Lewis' remarks by a few of his personal observations. The papers chiefly dwelt upon were Professor Norris' paper on "The Technically Trained Man and the Electric Railway Industry", the report of the standardization committee, the report

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on rail corroding, and Mr. Bibbins' paper on the " Fort Wayne and Wabash Valley Traction Co ".

Mr. Green, P. G. then described most interestingly his year's experience in the apprenticeship course of the Bullock Electric Manufacturing Co. This was of especial interest because Mr. Green is the only man from our Institute who has been through the Bullock apprenticeship course.

The next two speakers, Mr. Law, '08, and Mr. Nims, '08, related their experiences with telephone work. Mr. Law had to do with trouble-hunting on the operating end in Providence, and Mr. Nims spoke of the installations in the Newtown, Pa. exchange.

S. W. Farnsworth, P.G., gave a short account of the Institute Convention at Niagara Falls, at which he represented our Branch. Mr. Farnsworth spoke more of the men who took part than of the papers presented, and reported a most enjoyable and instructive time. He advised all who can possibly do so to attend the next convention.

The Branch held a very successful meeting on Nov. 8, there being 165 in attendance. Professor J. O. Phelon and C. D. Knight, of the electrical engineering department, are the ones to whom special credit is due; they gave a lecture entitled " Experiments Illustrating Modern Applications of Electricity ".

Only some of the experiments can be outlined. The property which some non-conductors have of becoming conductors at high temperatures, as illustrated in the Nernst lamp, was shown. The images of direct-current, alternating-current, flaming, and magnetite arcs were thrown on a screen and their peculiarities pointed out. Electric welding and the use of the electric forge were shown, also holes were burned through a steel plate by means of an electric arc. One of the most curious things was an electric motor so connected that, instead of revolving continually in one direction, it would speed up for a few revolutions, then reverse and speed up for a few revolutions in the other direction, and keep continuing these reversals.

At the close of the lecture the audience adjourned to the large General Laboratory, where doughnuts, cheese, and cider were served. The supply of cider was in a keg suspended from the travelling crane; thus the different points of consumption were easily kept supplied. A quartet in the gallery added much to the pleasure during the social hour.

Minutes of October Meeting of the Institute

Meeting of the American Institute of Electrical Engineers, held in the Auditorium of the Engineers' Building, 33 West Thirty-ninth street, New York, Friday, October 11, 1907. President Stott called the meeting to order at 8:20 o'clock, and then delivered his

Inaugural Address

" Before entering upon the presentation and discussion of the papers prepared for this occasion, we may profitably pause for a few moments to consider the aims and objects of this Institute, as set forth in Article I of our Constitution, and how we have accomplished them in the past, and how we may endeavor more fully to meet them in the future.

The American Institute of Electrical Engineers to-day has over 5100 members, of whom approximately 90% are residents of this country, and 10% residents of foreign countries. Of the 4600 domestic members, approximately 22% reside within one hour's travel of our national headquarters, and 70% within a distance which can be covered in twelve hours or less.

Our PROCEEDINGS and TRANSACTIONS, available to all, undoubtedly are the most valuable asset of membership; but next to that may we not say that the social side ranks next in value? It is obviously impossible for us all to meet one another, as our domestic membership alone is distributed over a territory of 2,970,000 square miles. To meet

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this difficulty, however, the Sections and University Branches have been organized, so that now besides the national headquarters in New York, we have 20 Sections and 17 University Branches located at all great centers of membership. At these Sections and Branches, not only are the papers presented at the New York meetings discussed, but original papers are also presented and discussed. Papers presented at Sections will, when forwarded to the Papers Committee, be disposed of in exactly the same manner as if presented for the New York meeting.

In accordance with the terms of the new Constitution, now in force, the chairmen of all Sections are *ex-officio* members of the Sections Committee, and have the right to appear before the Board of Directors at any of their meetings for the purpose of conference in regard to any matters pertaining to the affairs of the Institute in their Sections.

It will thus be seen that we are gradually evolving an organization somewhat similar to that of our state and federal governments, and as the process of evolution goes on, the Constitution may have again to be readjusted to meet new conditions.

Article I of our Constitution says:

> 1. The name of this association is the American Institute of Electrical Engineers.
> 2. Its objects shall be the advancement of the theory and practice of Electrical Engineering and of the allied Arts and Sciences and the maintenance of a high professional standing among its members. Among the means to this end shall be the holding of meetings for the reading and discussion of professional papers and the publication of such papers, discussions and communications as may seem expedient.

When we look back over our TRANSACTIONS for the last ten years, we can not help being struck by the admirable way in which we find there recorded almost everything of note which has contributed to the "advancement of the theory and practice of Electrical Engineering," but so rapid has the evolution of the theory and practice of electrical engineering been, that the "allied Arts and Sciences" have been to a large extent squeezed out. With every new application of electricity, comes the demand for men who not only are specialists in that particular art, but who at the same time are electrical engineers; as, for example, in the applications of electricity to electro-chemical processes, railways, illumination, transmission of power, mining, utilization of electricity in the numberless manufacturing processes—all of them calling for highly specialized knowledge in the allied arts.

It would therefore seem as if the time were now ripe for carrying out all the objects mentioned in our Constitution, and the Papers Committee is now endeavoring to broaden the scope of the Institute work without allowing their efforts to scatter too much. In order to assist in this work, some of the committee work has been reorganized; for example, the old High-Tension Transmission Committee, which has done such excellent work, now becomes a sub-committee of the Papers Committee, and a new sub-committee on Railways has been formed. This reorganization will, it is hoped, relieve the Papers Committee, and coördinate the work which previously had a natural tendency to duplication under two independent committees. Additional sub-committees will be appointed as necessity seems to require.

In accordance with the unanimous vote at the last Annual Convention, the Board of Directors has authorized the appointment of a Committee on Education to coöperate with other educational committees in recommending a syllabus of studies for electrical engineers at our universities.

In furtherance of this work, a special meeting devoted to educational subjects will be held toward the end of this year, when those in charge of educational work will be free to devote some time to this most important subject.

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In connection with educational work we have available to our members, not only our own library but also those of the American Society of Mechanical Engineers and the American Institute of Mining Engineers, aggregating approximately 30,000 volumes, and forming the most valuable collection of technical works in the world. This joint library, however, is only open from 9 a.m. to 5 p.m., and is therefore of very little value to the majority of members, who are unable to spare time from their various vocations between these hours; but a movement is now on foot to change the present organization so as to make the library available up to 10 p.m., and thus enable our members to make full use of this great opportunity to consult the best authorities on any engineering subject.

When distinguished foreign engineers visit this country, we have had no person or persons who could officially welcome them in the name of the American Institute of Electrical Engineers, so that this duty or pleasure has fallen heavily upon a small number of members, who have on numerous occasions acted as an unofficial reception committee. It would seem therefore as if it would lend to the dignity of these receptions, whilst giving authority to our members who are willing to incur the necessary expenditure of time and money, if a strong representative reception committee were appointed in each large city, so that our guests could be passed on from one city to another and thereby be saved a great deal of trouble, by finding out immediately where they could see the particular apparatus or get the information they desired.

In conclusion, it now seems probable that our annual banquet will be held in January, when we hope to have several distinguished guests address us. And I trust that the members of the American Institute of Electrical Engineers will remember that not only in our technical work, but in our social work, our officers, whom we have elected, need our constant support and encouragement."

The following papers were then presented:

1. The Grounded Neutral, with and without Series Resistance, in High-tension Systems, by Paul M. Lincoln.

2. Experience with a Grounded Neutral on the High-tension System of the Interborough Rapid Transit Company, by George I. Rhodes.

3. The Grounded Neutral, by F. G. Clark.

These papers were then discussed by Messrs. Peter Junkersfeld, Philip Torchio, N. J. Neall, J. B. Taylor, Carl Schwartz, C. W. Stone, F. B. H. Paine, Chas. F. Scott, Paul M. Lincoln, George I. Rhodes, Chas. P. Steinmetz, O. S. Lyford, Jr., and Frank G. Baum.

International Electrotechnical Commission.

The International Electrotechnical Commission has been organized as recommended by the Saint Louis Congress in order that a permanent and authoritative body might be called upon to act in determining certain questions that have heretofore been passed upon by international congresses. The selection of a national committee for the United States to coöperate with the commission was delegated to the American Institute of Electrical Engineers and the appointments have now been made as follows:

Elihu Thomson, Lynn, Mass, president.

Charles F. Scott, Pittsburg, Pa., first vice-president.

Samuel Sheldon, Brooklyn, N. Y., second vice-president.

Bion, J. Arnold, Chicago, Ill.
Arthur W. Berresford, Milwaukee, Wis.
John J. Carty, New York City.
W. C. L. Eglin, Philadelphia, Pa.
Carl Hering, Philadelphia, Pa.
John W. Howell, Harrison, N. J.
Dugald C. Jackson, Boston, Mass.
Francis W. Jones, New York City.
Arthur E. Kennelly, Cambridge, Mass.

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Benjamin O. Lamme, Pittsburg, Pa.
W. A. Layman, St. Louis, Mo.
John W. Lieb, Jr., New York City.
Clayton H. Sharp, New York City.
Charles P. Steinmetz, Schenectady, N. Y.
Lewis B. Stillwell, New York City.
Henry G. Stott, New York City.
Samuel W. Stratton, Washington, D.C.

Other countries will be represented upon the commission by similar national committees.

The central office has been established in London, with a permanent secretary.

Minutes of November Meeting of the Institute

The two hundred and twenty-second meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 West Thirty-Ninth street, New York, Friday November 8, 1907. President Stott called the meeting to order at 8:20 p.m.

The Secretary announced that at the meeting of the Board of Directors held during the afternoon there were 80 Associates elected, as follows:

ACTON, EDWARD HARKER, Apprentice, Westinghouse Electric and Mfg. Co.; res., 1108 Center St., Wilkinsburg, Pa.

ANDREWS, ALFRED STEPHENSON, Electrical Work, 2 South Parade Road, Bangalore, S. India.

BARNES, LEWIS LOVE, Salesman, Westinghouse Electric and Mfg. Co., 1333 Candler Bldg.; res., 71 W. 15th St., Atlanta, Ga.

BJORGERD, THEODORE, Draftsman, Seattle Electric Co., 409 2d Ave., W., Seattle, Wash.

BRINKERHOFF, ALBERT DAVID, Engineer, Waco Gas and Electric Co., Waco, Texas.

BURGNER, LINNAEUS PETER, Foreman of Construction, F. Bissell Co.; res., 218 13th St., Toledo, O.

BURNS, PATRICK HENRY, Superintendent Telegraphs and Telephones, Bahamas Colonial Government, Nassau, Bahamas

BURRISS, JAMES REUBEN, Superintendent, Anderson Traction Co., Anderson, S. C.

CADWELL, GEORGE HARRY, Electrical Contractor, Calle, Victoria 11, Mexico City, Mex.

CARL, JOHN ROGER, Chief Operator, California Gas and Electric Corporation, Colgate, Cal.

CARR, HUGH STANLEY, Electrical Engineer, American Carbolite Co., West Duluth, Minn.

CLARK, ARTHUR REGINALD, Engineer's Inspector, Engineering Department, Southern Bell Telephone and Telegraph Co., Birmingham, Ala.

COLLER, LEON C., Power Engineer, Western Electric Co., 259 S. Clinton St., Chicago, Ill.

CONKLIN, LEANDER H., General Superintendent of Lighting, West Penn Railways Co., 136 E. Fairview Ave., Connellsville, Pa.

DEREMER, JAY GRANT, Assistant to General Manager, Westinghouse Electric and Mfg. Co., 2d and Natoma Sts., San Francisco, Cal.

DONALDSON, GEORGE C., Master Mechanic, Buffalo and Susquehanna Coal Mining Co., 131 E. Washington DuBois, Pa.

ELBERSON, J. C., Electrician, Philadelphia Electric Co.; res., 941 N. 48th St., Philadelphia, Pa.

EVANS, HARRY WILLIS, Testing Engineer, Chicago Edison Co.; res., 550 LaSalle Ave., Chicago, Ill.

EVANS, LLEWELLYN, Wireman, R. H. Bradshaw & Co.; res., 2231 Dana St., Berkeley, Cal.

FENTON, HENRY GARFIELD, Assistant Engineer, Mexican Light and Power Co., 3a Colonia No. 6, Mexico City, Mex.

FULLER, ALMON B., Switchboard Engineer, H. Krantz Mfg. Co., 160 7th St.; res., 516 12th St., Brooklyn, N. Y.

GARDNER, THOMAS WEST, Electrical Engineer, Cumberland Telephone and Telegraph Co., Nashville, Tenn.

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GEIBEL, FRED EMANUEL, Engineer on Transmission, General Electric Co.; res., 7 N. College St., Schenectady, N. Y.

GELZER, JOHN, JR., Engineer and Salesman, Westinghouse Electric and Mfg. Co., Birmingham, Ala.

GILMARTIN, JOHN, Foreman Meter Department, Toledo Railways and Light Co., 2460 Broadway, Toledo, O.

GRAFTIO, HENRY, Assistant Chief Engineer, Westinghouse Company Ltd., St. Petersburg, Russia.

HARGER, ANDREW F., Superintendent of Transmission, Wilkes-Barre and Hazelton Railway & Lehigh Traction Co., Hazelton, Pa.

HARRISS, WILLIAM HENRY, President and General Manager, Four Cotton Mills; res., 1018 Century Bldg., Atlanta, Ga.

HEATHER, HENRY JAMES SHEDLOCK, Electrical Engineer, H. Eckstein & Co.; res., Overdale, Parktown, Johannesburg, S. A.

HEATON, HARRY HERBERT, Generating Station Operator, Helena Power Transmission Co., Hauser Lake, Mont.

HEINZE, CARL AUGUSTUS, Assistant with E. F. Scattergood, 536 Citizens' National Bank Building; res., 1788 W. 24th St., Los Angeles, Cal.

HENDERSON, DWIGHT FIRMAN, Light and Power Department, Washington Water Power Co., Spokane, Wash.

HONOLD, PAUL HERMAN, Electrical Construction Engineer, Allis-Chalmers Co., Port Washington; res., Sheboygan, Wis.

HOUSTON, GEORGE RICHARD, Foreman, Switchboard Installation Department Western Electric Co., 1814 2d Ave., Birmingham, Ala.

HULTS, EUGENE ARTHUR, Assistant Electrical Foreman, Universal Portland Cement Co., Buffington, Ind.; res., 6333 Stewart Ave., Chicago, Ill.

JENKINS, GEORGE RICHARD, Superintendent Underground Cables, Mexico Light and Power Co., Mexico City, Mex.

JOFFE, GEORGE A., Draftsman, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.

JOHNSON, WALTER LYULPH, Manager Bell Brothers Ltd., Clarence Iron Steel Works, Port Clarence, Middlesex, England.

KEARNS, J. EDWARD, Commercial Engineer, General Electric Co.; res., 612 South Ave., Schenectady, N. Y.

KEELY, ROYAL R., Chief Engineer, City of Edmonton, Alberta, Canada.

KOHLHAAS, HERMAN THEODORE, Division Inspector in Final Inspection Department, Western Electric Co., 463 West St., New York City.

LAURENCENA, MIGUEL JUAN, Third Class Engineer, Argentine Navy, Calle Estados Unidos 1332, Buenos Aires, Arg. Rep.

LAYNE, WILLIAM ROBERT, Chief Electrical Engineer, with Geo. J. Wellington; res., 1810 Vine St., Berkeley, Cal.

LUNDELL, ALBEN EMANUEL, Telephone Engineer, Western Electric Co.; res., 1272 Wilton Ave., Chicago, Ill.

McFARLIN, JOHN ROBERT, Electrical Engineer and Chemist, Gorton Daniels Electric Co., 18 N. 11th St., Keokuk, Iowa.

MILLS, NATHANIEL CHILD, Engineer, General Electric Co.; res., 227 Liberty St., Schenectady, N. Y.

MORGAN, JOSIAH FOSTER, Manager, Thomas Engineering Co., 13 N. Wyoming St., Hazelton, Pa.

MAHOOD, EDWIN TERRELL, Cable Engineer, Bell Telephone Co. of Mo., 3844 Olive St., St. Louis, Mo.

MANN, ALBERT BARCLAY, Electrical and Mechanical Engineer, American Laundry Machinery Mfg. Co., Cincinnati, O

MARSHALL, PERCY MACLEAN, Telephone Engineer, Western Electric Co., 463 West St.; res., 150 E. 37th St., New York City.

NAKAHARA, IWASABUROW, Chief Engineer, Tokyo Electric Light Co., No. 3 Yurakucho, Kojimachiku, Tokyo, Japan.

NELSON, LEROY SYLVESTER, Construction Foreman, General Electric Co., Schenectady, N. Y.

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PECK, WALTER TOUCEY, Electrical Engineer, W. R. Grace & Co., Valparaiso, Chili.

PHILLIPS, FRANK REITH, Investigating Engineer, Ohio Brass Co., Mansfield, Ohio.

PHILLIPS, WALTER P., Manager, Printing Department, American Graphophone Co.; res., 971 Fairfield Ave., Bridgeport, Conn.

PREACHER, GEOFFREY LLOYD, Consulting Engineer, Lombard Iron Works and Supply Co., Augusta, Ga.

PRIEST, JAMES HARRY, Student, New Hampshire College, Durham; res., Manchester, N. H.

RANDALL, HENRY DENISON, Sales Engineer, Westinghouse Electric and Mfg. Co., 424 1st Ave., Spokane, Wash.

ROBERTS, GEORGE B., Engineer, Citizens Tel. Co., St. Joseph, Mo.

ROGERS, WILLIAM GEORGE, Electrical Foreman, Philadelphia Electric Co.; res., 1327 S. Wilton St., Philadelphia.

ROSS, DOUGLAS GOODERHAM, Testing Department, General Electric Co., Schenectady, N. Y.; res., 481 Sherbourne St., Toronto, Ont.

ROYLANCE, LEON ST. DENIS, Electrical Engineer and Draftsman, Equipment Office U. S. Navy, Union Iron Works; res., 1278 Turk St., San Francisco, Cal

SIEBENMORGEN, WILLIAM, Chief Engineer, C. and C. Electric Co., Garwood; res., Westfield, N. J.

SMITH, LLOYD LYMAN, 1721 4th St., S. E., Minneapolis, Minn.

SOPER, ARTHUR JOHN, Railway Engineering Department, General Electric Co.; res., 702 Campbell Ave., Schenectady, N. Y.

STERN, FERDINAND, Interstate Electric Co., New Orleans, La.

STRACHAN, JAMES FORREST, Engineering Department, Pacific Tel, and Tel. Co.; res., 1592 Fulton St., San Francisco, Cal.

TALTAVALL, THOMAS R., Assistant Editor, *Electrical World*, 239 W. 39th St., New York City; res., Montclair, N. J.

THOMAS, CARL N., Draftsman, Narragansett Electric Lighting Co., 25 South St., Providence, R. I.

THOMAS, ROY NORTHROP, Operating Electrician, Oneida Railway Co., Utica; res., Monoa, N. Y.

THOMPSON, CORNELIUS, Ames Bonner and Co.; res., 70 Federal St., Toledo, Ohio.

THOMSON, ARTHUR BOYDEN, Special Agent, C. S. Knowles, 120 Broadway; res., 150 Central Park South, New York City.

WAINWRIGHT, RICHARD BROWER, Equipment Record Clerk, American Telephone and Telegraph Co.; res., 177 W. 83d St., New York City.

WEMAN, KLAS, Manager and Chief Engineer, L. W. Ericsson Tel. Mfg. Co.; res., 701 Potomac Ave., Buffalo, N.Y.

WICKSTROM, JOSEPH ERNEST, Assistant to Superintendent, Seattle-Tacoma Power Co., 614 Madison St.. Seattle, Wash.

WILDE, HERBERT RUSSELL, Shift Engineer, Mexican Light and Power Co., Ltd., Necaxa, Puebla, Mexico.

WILSON, JAMES RAE, 1004 Simpson St., Bronx, N.Y.

WOODRESS, JAMES LESLIE, Electrical Engineer, Century Electric Co.; res., 722 Aubert Ave., St. Louis, Mo.

WYNN, ROBERT MANSFIELD, Electrician, Tagona Water and Light Co., Lake Superior Corporation, Sault Ste Marie, Ont.

YOUNG, CHARLES ROBERT, Telephone Engineer, Western Electric Co.; res., 101 Essex Ave., Bloomfield, N. J.

The Secretary announced further that the following Associates were transferred to the grade of Member.

CLIFFORD WAYNE HUMPHREY, Consulting and Designing Engineer, "The Rookery," Chicago, Ill.

ROBERT CARR LANPHIER, Secretary and Manager, Sangamo Electric Company, Springfield, Ill.

ALBERT GUSTAV WESSLING, Assistant Engineer, The Bullock Electric Manufacturing Company, Cincinnati, O.

WILLIAM NELSON SMITH, Electric Traction Engineer, Westinghouse, Church, Kerr & Company, New York City.

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CHARLES EZRA SCRIBNER, Chief Engineer, Western Electric Company, Chicago, Ill.

KEMPSTER B. MILLER, Consulting Electrical Engineer, 1454 Monadnock Block, Chicago, Ill.

President Stott announced that Professor Morgan Brooks of the University of Illinois had so arranged the Eastern inspection trip of the senior class in electrical engineering at the university that they were able to be present at this meeting. The party consisted of Professor Brooks and thirty-five students.

The Secretary announced that until further notice the libraries of the three founder societies — the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers would be open every week day from 9 o'clock a.m., until 9 o'clock p.m.

A paper entitled "Comparative Performance of Steam and Electric Locomotives" was then presented by Albert H. Armstrong, of the General Electric Company.

The paper was then discussed by Messrs. Cary T. Hutchinson, N. W. Storer, W. S. Murray, William McClellan, W. J. Wilgus, C. L. de Muralt, W. N. Smith, B. F. Wood, Chas. P. Steinmetz, and A. H. Armstrong.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the Secretary before January 10, 1908.

6806 R. C. Beardsley, Cleveland, O.
6807 W. R. Cook, Norfolk, Va.
6808 M. L. Elder, Pittsfield, Mass.
6809 J. H. Stubbs, Toronto, Ont.
6810 D. T. Williams, Philadelphia, Pa.
6811 L. N. Crichton, Grace, Idaho.
6812 W. N. Parsons, Tacubaya, Mex.
6813 M. B. Stewart, Santa Barbara, Mex.
6814 S. O. Swenson, Detroit, Mich.
6815 H. C. Adams, Jr., New York City.
6816 J. N. DuBarry, Jr., New York City
6817 H. K. English, Schenectady, N. Y.
6818 H. A. Hornor, Camden, N. J.
6819 F. N. Koziell, New York City.
6820 F. C. Lavarack, New York City.
6821 P. G. Lapat, Cheyenne, Wyo.
6822 R. B. McDonnough, Three Rivers, Ore.
6823 H. D. Penney, Pittsfield, Mass.
6824 J. M. Andersen, Dorchester, Mass.
6825 August Berggren, Stockholm.
6826 G. E. Brown, Redfield, S. D.
6827 E. W. Bowness, Calgary, Can.
6828 Edwin Ballman, St. Louis, Mo.
6829 C. G. Barrett, Norfolk, Va.
6830 C. G. Beckwith, Collingwood, O.
6831 H. O. Dutter, Bucyrus, O.
6832 W. S. Devlin, New Castle, Pa.
6833 T. Koyama, Nagoya, Japan.
6834 F. J. Rickey, Covington, Ky.
6835 L. W. Webb, Norfolk, Va.
6836 F. W. Walter, Norfolk Va.
6837 F. W. Willey, Allston, Mass.
6838 W. F. M. Goss, Urbana, Ill.
6839 F. D. Bartlett, Philadelphia, Pa.
6840 C. W. Bender, Altoona, Pa.
6841 H. G. Butterfield, E. Pittsburg, Pa
6842 C. L. Cadle, Rochester, N. Y.
6843 C. W. Chappelle, Cleveland, O.
6844 S. W. Farnsworth, Lancaster, Mass.
6845 H. G. Otis, New York City.
6846 R. H. White, Schenectady, N. Y.
6847 L. B. Abbott, Lynn, Mass.
6848 H. T. M. Cobson, Mexico City, Mex.
6849 C. B. Fairchild, Jr. Cleveland, O.
6850 A. P. Good, Chicago, Ill.
6851 H. W. Jones, Garrettsville, O.
6852 P. J. Murley, New York City.
6853 Max Neuber, Toledo, O.
6854 J. P. Rochwood, New York City.
6855 C. R. Wylie, Cincinnati, O.
6856 H. L. West, St. Louis, Mo.
6857 R. W. Brodmann, Rockaway Park, L. I., N. Y.
6858 H. C. Iffland, New York City.
6859 Raymond Roth, Philadelphia, Pa.

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6860 J. S. Stubbefield, Wilkinsburg, Pa.
6861 R. A. Smith, Norfolk, Va.
6862 G. B. Ferrier, Jr., New York City.
6863 A. S. Miller, Baltimore, Md.
6864 C. C. Beck, Mansfield, O.
6865 W. D. Eaton, Joliet, Ill.
6866 T. F. Judge, New York City.
6867 H. E. Geiser, Philadelphia, Pa.
6868 C. J. Hopkins, New York City.
6869 H. L. Price, Toronto, Ont.
6870 R. S. Pattison, Clayton, Mo.
6871 Norman Read, Denver, Colo.
6872 A. E. Reynolds, Mexico City, Mex.
6873 B. A. Stowe, Cleveland, O.
6874 W. E. V. Shaw, Toronto, Ont.
6875 B. F. Selby, Toronto, Ont.
6876 L. V. Lewis, Vernon, N. Y.
6877 Felix Stern, Chicago, Ill.
6878 H. I. Emanuel, Pittsburg, Pa.
6879 J. B. Martin, New York City.
6880 J. D. Ross, Seattle, Wash.
6881 G. H. Duffield, Rock Island, Ill.
6882 C. R. Norberg, Cleveland, O.
6883 H. J. Strobel, New York City.
6884 C. P. Cooper, Durham, N. H.
6885 D. C. Durland, New York City.
6886 Paul Dieny, New York City.
6887 A. L. Williams, Fond Du Lac, Minn.
Total, 82.

Personal

Mr. Harold Morecroft, instructor at Syracuse University for the last two years, is now at Pratt Institute, Brooklyn, in charge of the electrical laboratory.

Mr. W. C. Wagner, formerly erecting electrical engineer, of Seattle, has been appointed superintendent of construction of a steam-turbine electric installation, at Woonsocket, R. I.

Mr. Harvey S. Pardee, formerly with the John A. Roebling's Sons Company, of Trenton, N. J., is now attending the Massachusetts Institute of Technology, at Boston, Mass.

Mr. David D. Gibson, Jr., has left the Westinghouse Electric & Manufacturing Company to take charge of a sub-station at Washington, D. C., for the Capitol Traction Company.

Mr. W. Anderson, formerly engineer and manager for the Cascade Water Power and Light Company, is now acting as engineer for the West Kootenay Power and Light Company, at Rossland, B. C.

Mr. Louis E. Reynolds, formerly with the San Francisco Gas and Electric Company, is now with the construction department of the Central Colorado Power Company, at Colorado Springs, Colo.

Mr. William J. Berry, instructor in mathematics at the Polytechnic Institute of Brooklyn, is at Harvard University on leave of absence. His present address is 15 Conant Hall, Cambridge, Mass.

Mr. A. S. Kalenborn is now vice-president of F. G. Baum and Company, of San Francisco, having charge of the business of the company in the Northwest, being located at Seattle, Washington.

Mr. Arthur I. Sundheimer, a graduate from the School of Applied Science of Columbia University, has accepted a position in the testing department of the General Electric Company at Schenectady.

Mr. J. E. Currie has left the employ of the Dayton Lighting Company, at Dayton, Ohio, and entered Cornell University as a special student in the mechanical and electrical engineering branches.

Mr. Charles E. Anderson has left the American Electrical Works at Phillipsdale, R. I., to take the position of superintendent and electrical engineer with the Willyoung Appliance Company at Yonkers, N. Y.

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Mr. Milton K. Akers, formerly assistant instructor in electrical engineering at the University of Illinois, is now instructor in electrical engineering at the Washington Agricultural College, Pullman, Washington.

Mr. Otto Holstein, until recently a district inspector in the Bureau of Posts of the Philippine Islands, with station at Ormoc, Leyte, P. I., is now with the Atlantic De Forest Wireless Company at 42 Broadway, New York City.

Mr. R. H. Pinkley, until recently chief draughtsman with the Union Electric Light and Power Company of St. Louis, has been transferred to a similar position with the Milwaukee Electric Railway and Light Company.

Mr. F. A. Hall has left the Ingersoll-Rand Company of New York to take a position as assistant engineer on alternating current and direct current turbogenerators, with the General Electric Company, at West Lynn, Mass.

Mr. Robert Hawxhurst, Jr., Assoc. Mem. Am. Soc. C. E., Assoc. Mem. Inst. E. E., Assoc. Inst. M. M., M.A.I. M.E., etc., has become general manager of the Poderosa Mining Company of Collahuasi, Chile, South America.

Mr. E. R. Carichoff has given up his office as consulting engineer at 20 Broad street, New York City, to take a position in the railway engineering department of the General Electric Company at Schenectady, N. Y.

Mr. Constantin Zorawski has given up his position as electrical engineer for the Allgemeine Elektricitats Gesellschaft, at Riga, Russia, and has become head engineer to the Volta Electrical Manufacturing Company, in Reval.

Mr. W. R. C. Corson, consulting electrical engineer of New York City, has accepted a position as assistant engineer with the Hartford, Ct., Steam Boiler Inspection and Insurance Company, and has discontinued his private practice.

Mr. W. S. Jackson has resigned from the transmission department of the Long Island Railroad Company, to engage in manufacturing the W. S. Jackson automatic block signal for electric railways, of which he is the inventor, at York, Pa.

Mr. W. H. Thompson, who has been connected since June, 1906, with the St. Paul Gas Light Company, as assistant to the general manager, has become general manager of the Union Light, Heat, and Power Company of Fargo, North Dakota.

Mr. George Lawson, who has been with the General Electric Company for a year, is now with Messrs. Warwick, Mitchell and Company, of New York City, his present work being in connection with street railway and engineering properties.

Mr. V. H. Hurdell, of New York, formerly in the Boston office of the Westinghouse Electric and Manfacturing Company, has entered the employ of the Thomas Engineering Company of Allentown, Pa., as travelling representative.

Mr. Rodolfo Roth, formerly with Victor M. Braschi & Company, consulting engineers and contractors, located in Mexico City, has been appointed assistant manager of the Aguascalientes Electric Light and Power Company, at Aguascalientes, Mexico.

Mr. Wyatt H. Allen, of the firm of Hunt, Dillman, Meredith, and Allen Incorporated, has removed from the temporary quarters at 202 California street, occupied immediately after the fire, to Rooms 907-912, Union Trust Building, San Francisco, Cal.

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Mr. H. D. Hawkes has been assigned by the General Electric Company to conduct all commercial negotiations between that company and the New York, New Haven and Hartford Railroad Company, and its allied concerns, with an office in New Haven, Conn.

Mr. Grover G. Rehfield, formerly construction engineer with The Bullock-Allis-Chalmers Company, will hereafter be associated with the Chicago Portland Company, at Oglesby, Illinois, as electrical engineer, to have charge of a 4500-h.p. alternating-current plant.

Mr. Joseph B. Baker, electrical engineer, formerly technical editor of the technological branch U. S. Geological Survey, Washington, D. C., resigned October 1, and is engaged in technical and engineering publicity work with offices at the " Mendota," Washington, D. C.

Mr. H. A. Pressey has left the firm of Hugh MacRae and Company, bankers, and opened an engineering office in the Hibbs Building, Washington, D. C., in connection with Mr. Francis R. Weller Mr. Pressey will continue engineering practice in hydraulic and electrical work.

Mr. John H. Finney, associated with the Aluminum Company of America at Pittsburg, has been transferred to Atlanta, Ga., where he has opened a southern office for this company. Mr. Finney hopes by this move to get in touch with the southern membership of the Institute.

Mr. George W. Simpson, for the past ten years a salesman in the detail department, Philadelphia office of the Westinghouse Electric and Manufacturing Company, is now sales agent for the Flexible Compound Company, in the exhibition department of the Philadelphia Bourse.

Mr. Myron Creese has left Almon City, Pa., and is now in charge of the physics work at the Maryland Agricultural College, at College Park, Maryland, where he expects to outline an electrical engineering course, and fit up a laboratory which will be open to students in the fall of 1908.

Mr. J. H. Seaman, formerly assistant engineer of the Consumers' Electric Company of New Orleans, La., has recently returned from a trip to Nicaragua, in the interest of the Topaz Mining Company, and has accepted the position of superintendent of the City Electric Light and Water Works at Alexandria, La.

Mr. S. J. Houston, of the General Electric Company's construction department, has finished the large cable installation of which he was in charge at Dayton, Ohio, and is now temporarily located at the General Electric office in Pittsburg, Pa., in charge of a cable installation for the Pittsburg Railways Company.

Mr. Charles H. Van Slyk, formerly in the New York office of the General Electric Company, has been appointed electrical engineer and assistant to president of the Coney Island and Brooklyn Railroad Company of Brooklyn, N. Y. The company is about to change its system from direct to alternating current.

Mr. W. Edgar Reed, formerly with the Westinghouse interests in Paris and at East Pittsburg, has gone into general consulting work, with an office in the Machesney Building, Pittsburg, Pa. Mr. Reed has had long experience in designing continuous- and alternating-current machinery, and induction motors, and in their practical application.

Mr. Orville H. Ensign has been appointed to the chair of electrical engineering at the University of Wisconsin, recently made vacant by the resignation of Professor Dugald C. Jackson. Professor Ensign is recognized as a pioneer in the electrical profession, hav-

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ing been identified with undertakings of magnitude and importance for the last twenty years.

MR. F. G. STEWART, general foreman at the shops of the Memphis, Tennessee, Street Railway, has accepted the position of general superintendent railway department of the Texarkana Gas and Electric Company, Texarkana, Ark-Tex. Mr. Stewart has been identified with street railways for over seventeen years, and for the last fourteen years with the Memphis Street Railway.

MR. W. W. MOORE, formerly manager of the engineering department of the Wesco Supply Company, St. Louis, Mo., has moved to Birmingham, Ala., as manager of a branch house to be established by the company at that place. He has a temporary office No. 608 First National Bank Building, Birmingham, Ala., but expects to have the new branch house started early in the coming year.

MR. EDGAR H. BERRY, has resigned his position as chief engineer of the Remington Typewriter factory, to enter independent business in New York. A banquet was tendered to Mr. Berry by 80 of the foremen and assistants at the factory on October 22, and he was also presented with a diamond stud as a token of remembrance and esteem from his associates in the typewriter works.

MR. CHAS. L. BROWN, formerly assistant to the manager of the electrical department of Allis-Chalmers Co., in charge of steam-turbine and turbine-alternator sales, has entered the manufacturing field and established the Economy Tool Company, at Wauwatosa, Wisconsin. Mr. Brown will manufacture an entirely new line of pneumatic hammers, and a new variable-stroke power hack-saw.

MR. H. B. PRIESTLEY WICKS has left Messrs. A. E. Brown, of Christchurch, New Zealand, and is now in the employ of the General Electric Company at Schenectady, N. Y. While on his way to this country, Mr. Wicks sold to a large London firm of instrument makers and electricians the patent rights of an electrical train and trolley-car stopping-place indicator, a New Zealand invention, patented by A. E. Brown and H. T. Smith.

MR. GILBERT ROSENBUSCH, Member of the Institution of Electrical Engineers, and Associate Member of the Institution of Civil Engineers in London, has left the Underground Electrical Railways Company of London, and opened an engineering office at Queen Anne's Chambers, Westminster, London, S. W. He will undertake engineering reports, investigation, and technical supervision, both in England and on the Continent.

MR. EDW. SCHILDHAUER, formerly with the Washington office of the Isthmian Canal Commission as electrical and mechanical engineer, has been transferred to Culebar, Canal Zone, Panama, where he will have charge of the design of power plants and operating machinery for the locks, movable dams, and regulating works. He will also study the water supply for the power plants, and the feasibility of electrifying the re-located Panama railroad.

MR. PERCY H. THOMAS, for fourteen years connected with the Westinghouse interests, has formed with N. J. Neall, consulting engineer of Boston, the firm of Thomas and Neall, electrical engineers, with offices in New York and Boston. The firm will do general consulting work in electrical engineering, giving special attention to high-tension design, extra-high-tension practice, lightning protection, and special electrical problems of all kinds.

MR. EDWARD M. WHARFF has been put in charge of the power-station, car-house, cars, overhead work, and all electrical equipment of the Syracuse, Lake Shore, and Northern Railroad Company

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at Syracuse, N. Y., Marked changes will be made both in power supply and cars for this road. Power purchased from the Niagara, Lockport, and Ontario Power Company, will be used, and cars will be equipped for operation by direct- and single-phase alternating current.

MR. BYRON T. BURT, for the last six years in charge of the Chattanooga Electric Company, is about leaving Chattanooga, where he built up a splendid power business, in addition to furnishing current for the extensive city and suburban street railway properties. Mr. Burt is one of the real pioneers of the central station industry, and has enjoyed a variety of experience, which includes work in Italy, Spain, Hungary, South America, the far West, and the extreme South of the United States.

Obituary.

ERNST DANIELSON died in Westeras, Sweden, in August last. He was born January 19, 1866, in Voxna; studied at Upsala, and, in 1883, was admitted as apprentice at the Arboga works of the Stockholm Electrical Co. In 1884 he entered the Technical High School at Stockholm, returning, after passing his final examinations in 1887, to the Arboga works. He came to the United States in 1890 and was first associated with the Wenström Consolidated Dynamo and Motor Co. of Baltimore, and afterwards with the Thomson-Houston Co., of Lynn, Mass, which later consolidated with the Edison Co., of Schenectady, forming the present General Electric Co., where he carried out a large amount of exceedingly responsible work. In 1892 he was chief engineer of the Allmanna Svenska Elektriska Aktiebolaget, of Westeras, Sweden. In 1895 he left that company to take up a consulting engineering practice in Sweden; preparing at the request of Dr. De Laval, proposals for utilizing the water power of the Trollhattan Falls. During the winter of 1897-8, Mr. Danielson again visited America, also most of the prominent electrical installations of Switzerland. and Italy. In 1900 he was appointed Technical Director of the Allmanna Svenska Elektriska Aktiebolaget of Westeras, Sweden, cocupying this position until 1903, when failing health compelled him to delegate most of his work to others. Mr. Danielson was also for some time chairman of the Swedish Institution of Civil Engineers; a member of the Royal Academy of Science, a member of the Institution of Electrical Engineers of Great Britain. He was elected an Associate of the American Institute of Electrical Engineers, June 27, 1895.

Mr. Danielson's most important pioneer work consisted of his researches in the three-phase system, and its utilization for power transmissions. The first work to be carried out was the well-known Hellsjön-Grängesberg power transmission, the success of which led to other power schemes. By this means Sweden has come into a position to utilize the national wealth represented in its water power, much earlier than would otherwise have been possible, and the product of the Swedish electrical industry has been enabled to take a prominent position in the international market.

Although his main work relates to electrotechnical science, Mr. Danielson was thoroughly at home in several other branches of engineering science. His knowledge of turbines and machinery for utilizing water power enabled him to realize clearly the features necessary for hydroelectrical installations, and his knowledge of rolling-mill and of mining machinery enabled him to appreciate the requirements to be met by electric motors for this kind of work. It is largely on account of this many-sidedness in technical knowledge at a time when electrical science was rapidly developing, that Mr. Danielson's work has been of such great value. Those who knew him personally will always remember him as a kind and true friend.

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Books Received

The following volumes have been received and placed in the Library of the Institute;

Electric Wiring, Diagrams and Switchboards. By Newton Harrison, E. E. 272 pages. New York, The Norman W. Henley Publishing Company. Price $1.50.

Contents.—Chapter I.—The Beginning of Wiring.—Calculating the Size of Wire. II.—A Simple Electric Light Circuit Calculated. III.—Estimating the Mains, Feeders and Branches. IV.—Using the Bridge for Testing. The Insulation Resistance. V.—Wiring for Motors. VI.—Wiring with Cleats, Moulding and Conduit. VII.—Laying out a Conduit System. VIII.—Power Required for Lamps. Lighting of a Room. IX.—Switchboards and their Purpose. X.—Switchboards Designed for Shunt and Compound Wound Dynamos. XI.—Panel Switchboards, Street Railway Switchboards, Lightning Arresters. XII.—The Ground Detector. Locating Grounds. XIII.—Alternating Current Circuits. XIV.—The Power Factor in Circuits. XV.—Calculation of Sizes of Wire for Single, Two- and Three-phase Circuits.

Electric Furnaces and Their Industrial Application. By J. Wright. A practical treatise of what has been done, and of what is being done, both experimentally and commercially, with the electric furnace. 288 pages. New York. The Norman W. Henley Publishing Co. Price $3.00.

Elements of Electrical Engineering. By William Suddards Franklin and William Esty. Vol. I. Direct Current Machines. Electric Distribution and Lighting. Illustrated. 517 pages. New York: The Macmillan Company. London: Macmillan & Co., Ltd. 1906. Second edition, fifth thousand. Price, $4.50 net.

Contents.—Classification and Notation. Chapter I.—Introduction. Elementary Electricity and Magnetism. II.—The Dynamo. III.—The Operation of the Dynamo as a Generator. IV.—The Operation of the Dynamo as a Motor. V—Power Losses in Generators and Motors. Efficiency. VI.—Ratings and Guarantees. VII.—The Practical Operation of Dynamos. Station Equipment. VIII.—Storage Batteries. IX.—Electric Distribution and Wiring. X.—Photometry and Electric Lighting. Appendix *A*. Electromagnets. Magnetism of Iron. Appendix *B*. Characteristic Curves. Appendix *C*. Armature Windings. Appendix *D*. Problems. Index.

Testing of Electro-Magnetic Machinery and Other Apparatus. By Bernard Victor Swenson, E.E., M.E., and Budd Frankenfield, E.E. Vol. I. Direct Currents. Illustrated 420 pages. New York: The Macmillan Company. London: Macmillan & Co., Ltd. 1905. Price, $3.00 net.

Contents.—Nomenclature. List of References. List of Experiments. Preliminary. Instruments. Experiments. Appendix *A*. Shop Tests. Appendix *B*. Standardization Report (A.I.E.E.) Index.

Elementary Electricity and Magnetism and Their Applications. By Dugald C. Jackson, C.E., and John Price Jackson, M.E. Illustrated. 482 pages. New York: The Macmillan Company. London: Macmillan & Co., Ltd. 1907. Price, $1.40 net.

Contents.—Chapter I.—The Nature and Properties of Electricity. II.—Additional Characteristics of Electric Charges. III.—Electric Potential, Electrical Machines, and Electrical Capacity. IV.—Electric Batteries, or Appliances for Transforming Chemical Energy into Electrical Energy. V.—Electrolysis. VI.—The Nature and Properties of Magnetism. VII.—Electric Circuits and the Flow of Electricity; Ohm's Law. VIII.—Electrical Energy, Heating Effects of Electric Currents, and Miscellaneous Effects of Electric Currents. IX.—Electro-magnetism. X.—Electro-magnetic Induction. XI.—Galvanometers and Voltameters. XII.—Measurement of Electrical Resistance. XIII.—Measurement of Electric Currents and Pressures. XIV.—Measurement of Electrical Power. Condensers, and Measurement of Capacity. XV.—Principles and Construction of Direct-current Dynamos and Motors. XVI.—Alternating Currents and Alternating Current Machinery. XVII.—Arc and Incandescent Lighting. XVIII.—Power Stations, the Electric Railway, and Other Applications of Motors. XIX.—The Telegraph; the Telephone; Electric Bells. XX.—Line Construction and the Electric Distribution and Transmission of Power. XXI.—Applications of Electrical Instruments to the Testing of Lines and Circuits. Measurements of Illumination. XXII.—Electrolytic Deposition of Metals. Electric Smelting, Welding, Cooking, etc. XXIII.—Electro-magnetic Waves; Wireless Telegraphy; Roentgen Rays. Index.

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ALTERNATING CURRENTS AND ALTERNATING CURRENT MACHINERY. This is Vol. II of the Text-book on Electro-Magnetism and the Construction of Dynamos. By Dugald C. Jackson, C.E., and John Price Jackson, M.E. 729 pages. Illustrated. New York: The Macmillan Company. London: Macmillan & Co., Ltd. 1905. Price, $3.50 net.

CONTENTS.—Chapter I.—The Electric Pressure Developed by Alternators. II.—Armature Windings for Alternators. III.—Self-induction and Capacity. IV.—Graphical and Analytical Methods of Solving Problems in Alternating-Current Circuits. V.—The Magnetic Circuit of Alternators. VI.—Characteristics, Regulations, etc. VII.—Regulation and Combined Output. VIII.—Efficiencies, etc. IX.—Mutual Induction. X.—Operation of Ideal Transformer and Effect of Iron and Copper Losses. XI.—Efficiency and Losses in Transformers. XII.—Design of Transformers. XIII.—Polyphase Conducting Systems and the Measurement of Power in Polyphase Circuits. XIV.—Alternating-current Motors. XV.—Polyphase Transformers. Appendices. Index.

ELEMENTARY LESSONS IN ELECTRICITY AND MAGNETISM. By Silvanus P. Thompson, D.Sc., B.A., F.R.S., F.R.A.S. New edition, revised throughout with additions. Illustrated. 638 pages. New York: The Macmillan Company. London: Macmillan & Co., Ltd. 1906. Price, $1.40 net.

CONTENTS.—Chapter I.—Frictional Electricity. II.—Magnetism. III.—Current Electricity. IV.—Electrostatics. V.—Electromagnetics. VI.—Measurement of Currents, etc. VII.—Thermo-electricity. VIII.—Heat, Power, and Light, from Electric Currents. IX.—Inductance. X.—Dynamos and Transformers. XI.—Electro-Chemistry. XII.—Telegraphy. XIII.—Telephony. XIV.—Electric Waves. Appendix.

ILLUSTRATIONS OF THE C. G. S. SYSTEM OF UNITS WITH TABLES OF PHYSICAL CONSTANTS. By J. D. Everett, M.A., D.C.L., F.R.S., F.R.S.E. 283 pages. London: Macmillan & Co., Ltd. New York: The Macmillan Company. 1902. Price, $1.25 net.

CONTENTS.—Reduction to and from C. G. S. Measures. Interpolation by Second Differences. Chapter I.—General Theory of Units. II.—Choice of Three Fundamental Units. III.—Mechanical Units, Supplemental Section, on Physical Deductions from Dimensions. IV.—Hydrostatics. V.—Stress, Strain, Elasticity and Viscosity. VI.—Astronomy. VII.—Velocity of Sound. VIII.—Light. IX.—Heat. X.—Magnetism. XI.—Electricity. XII.—Rucker's Harmonizing of Dimensions, and Heaviside's "Rational Units." Appendix. Reports of Units Committee of British Association, and Resolution of Paris Congress. Index.

OUTLINES OF THE EVOLUTION OF WEIGHTS AND MEASURES AND THE METRIC SYSTEM. By William Hallock, Ph.D., and Herbert T. Wade, Octavo, 304 pages. Illustrated. Cloth, $2.25 net. The Macmillan Company, New York.

CONTENTS.—Chapter I.—Beginnings and Development of the Science of Metrology. II.—Origin and Development of the Metric System. III.—Extension of the Metric System Throughout Europe and Elsewhere. IV.—Weights and Measures in the United States. V.—The Metric System of To-day. Its Essential Characteristics and Fundamental Principles. VI.—The Metric System for Commerce. VII.—The Metric System in Manufacturing and Engineering. VIII.—The Metric System in Medicine and Pharmacy. IX.—International Electrical Units. X.—Standards and Comparison. Appendix. Tables of Equivalents and Useful Constants. Index.

STANDARD WIRING FOR ELECTRIC LIGHT AND POWER. By H. C. Cushing, Jr., M. A.I.E.E. Illustrated. 147 pages. New York: H. C. Cushing, Jr. Price, $1.00.

This work contains the National Electric Code explained and illustrated, together with the necessary tables and formulæ for outside and inside wiring and construction for all systems.

MODERN WIRING DIAGRAMS AND DESCRIPTIONS FOR ELECTRICAL WORKERS. 241 pages. Illustrated. By Henry C. Horstmann and Victor H. Tousley. Second edition, revised and enlarged. Chicago: Frederick J. Drake & Co. Price, $1.50.

CONTENTS.—Chapter I.—Call Bell Circuits, Bells, Dynamo Connections. II.—Annunciator Circuits. III.—Fire and Burglar Alarms. IV.—Telephone and Telegraph Circuits. V.—Electric Gas Lighting. VI.—Primary and Secondary Batteries. VII.—Connecting up. Locating Trouble. VIII.—Miscellaneous. IX.—Electric Lighting. X.—Arc Lamps, Nernst Lamp Cooper Hewitt Lamp. XI.—Recording Watt-

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meters. XII.—Direct Current Motors. XIII.—Automobiles, Charging Stations, Gas Engines. XIV.—Direct and Alternating Current Generators, Compensators. XV.—Alternating Current Motors, Transformers. XVI.—Armatures. XVII.—Switchboards, Ground Detectors. XVIII.—Storage Battery Connections. XIX.—Testing. XX.—Light. XXI.—Wiring Tables. XXII.—Electric Signs, Flashers, Display Lighting.

THE ELECTRO-PLATERS' HANDBOOK. By James H. Weston. 178 pages. Illustrated. Chicago: Frederick J. Drake & Co. 1905. Price, $1.00.

CONTENTS.—Electrical Rules and Formulas. Batteries. Electro-Plating with Batteries. Electro-Plating Dynamos. Electro-Platers Materials. Electro-Deposition of Metals. Cleaning the Work. Dips and Dipping. Stripping. Electro-Plating with Nickel. Electro-Plating with Silver. Electro-Plating with Gold. Electro-Plating with Copper. Electro-Plating with Zinc, Tin, Iron and Platinum. Electro-Plating with Alloys. Electro-Mechanical Plating. Cold Galvanizing and Galvanoplasty. Useful Information.

TEXT-BOOK OF ELECTRICAL MACHINERY Vol. I. Electric, Magnetic, and Electrostatic Circuits. By Harris J. Ryan, M.E., Henry H. Norris, M.E., and George L. Hoxie, M.M.E., Ph.D. First edition, second thousand. Illustrated. 258 pages. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. 1906. Price, $2.50.

CONTENTS.—Chapter I.—Electricity and Magnetism. II.—Fundamental and Derived Units. III.—Periodic Curves. IV.—Complex Quantities. V.—Laws of the Electric Circuit. VI.—Electric Power.

THEORY OF THE LEAD ACCUMULATOR (Storage Battery). By Dr. Friedrich Dolezalek. Translated from the German by Carl L. von Ende, Ph.D. (Goettingen). First edition. 241 pages. Illustrated. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. 1904. Price, $2.50.

CONTENTS.—Chapter I.—Chemical Theory of Origin of Current. II.—Thermodynamical Theory of Origin of Current. III.—Osmotic Theory of Origin of Current. IV.—Variation of Electromotive Force with Acid Concentration. V.—Variation of Electrode Potential with Acid Concentration. VI.—Temperature Coefficient. VII.—Influence of External Pressure. VIII.—Behavior During Charging and Discharging. IX.—Reversibility. X.—Changes in the Open Cell. XI.—Internal Resistance. XII.—Capacity. XIII.—Degree of Efficiency and Working Efficiency. XIV.—Changes in the Cell During Formation. XV.—Methods of Measurement. XVI.—Table of Density and Percentage Strength of Mixtures of Sulphuric Acid and Water.

ELECTRICAL WIRING AND CONSTRUCTION TABLES. By Henry C. Horstmann and Victor H. Tousley. 118 pages. Illustrated. Chicago: Frederick J. Drake & Co. 1907. Price, $1.50.

CONTENTS.—Chapter I.—Direct Current Wiring Tables. II.—Alternating Current Wiring Tables. III.—Economy of Conductors. IV.—Miscellaneous. V.—Calculation of Materials. VI.—Conduits and Wires. VII.—Tables of Carrying Capacities.

THEORY OF ELECTRICAL MEASUREMENTS. By William A. Anthony. Second edition, revised. First thousand. 94 pages. Illustrated. John Wiley & Sons. London: Chapman & Hall, Ltd. 1905. Price, $1.00.

CONTENTS.—The C. G. S. System of Units. The Magnetic Field. The Electric Current. Potential and Electromotive Force. Resistance and Ohm's Law. Practical Measurements of Electrical Quantities. Measurements of Resistance. Measurement of Current. Measurements of Potential. Testing and Calibrating Instruments. Heating Effects of the Current. Incandescent Lighting. Arc Lighting. Chemical Effects of the Current. Electromagnetic Induction. Electromagnetism.

CONTINUOUS CURRENT DYNAMO DESIGN. By H. M. Hobart, B.Sc., M.I.E.E., Mem. A.I.E.E. Illustrated. 220 pages. London and New York: Whittaker & Co. Price, $3.00.

CONTENTS.—Chapter I.—The Electric Conducting Circuit of the Continuous-Current Dynamo. II.—The Magnetic Circuit of the Continuous-Current Dynamo. III.—Armature Interference in the Continuous-Current Dynamo, and the Design of Field Spool Windings. IV.—The Proportioning of Continuous-Current Dynamos, and the Voltage Between Segments, and the Reactance Voltage. V.—Dynamo Design Coefficients. VI.—The Application of Reversing Poles to Continuous-Current Dynamos, and the Design

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of Continuous-Current Dynamos for High Speed and High Voltage. Appendix. Index.

MODERN ELECTRICAL CONSTRUCTION. By Henry C. Horstmann and Victor H. Tousley. 243 pages. Illustrated. Chicago: Frederick J. Drake & Co. Price, $1.50.

A reliable Practical Guide for the Beginner in Electrical Construction showing the Latest Improved Methods of Installing Work of all Kinds According to the Safety Rules of the National Board of Fire Underwriters.

ALTERNATING CURRENTS OF ELECTRICITY AND THE THEORY OF TRANSFORMERS. By Alfred Still, Assoc. M. Inst. C.E. Illustrated. 184 pages. London and New York: Whittaker & Co. 1898. Price, $1.50.

CONTENTS.—Magnetic Principles. Alternating Currents. Self-Induction. Capacity. Self-Induction and Capacity. Mutual Induction. Transformers.

INDUCTION COILS AND COIL MAKING. Construction, Operation and Application. By H. S. Norrie. Second edition, thoroughly revised and greatly enlarged. 290 pages. Illustrated. 5x6½ in. Cloth. Price, $1.00. New York: Spon & Chamberlain. London: E. & F. N. Spon. 1907.

CONTENTS.—Coil Construction. Contact Breakers. Insulations and Cements. Condensers. Experiments. Spectrum Analysis. Currents in Vacuo. Rotating Effects. Gas Lighting. Batteries for Coils. Storage or Secondary Cell. Tesla and Hertz Effects. The "Roentgen" Rays and Radiography. Wireless Telegraphy.

HANDBOOK FOR STREET RAILWAY ENGINEERS. By H. B. Andrews, C.E Second edition, first thousand. 199 pages. Illustrated. New York: John Wiley & Sons. 1903. Price, $1.25.

CONTENTS.—Chapter I.—Mensuration—Trigonometrical Formulæ. II.—Circular Curves. III. —Compound Transition Curves. IV.—Plain Curves. V.—Miscellaneous Information. VI.—Bending Moments. VII.—Strength of Materials. VIII.—Data for Estimates. IX.—Electrical Information. X.—Aluminum for Electrical Conductors. XI.—The Storage Battery. XII.—Tables. XIII.—Relative Percentages of Expenditures to Gross Receipts for Street Railways in Massachusetts. XIV.—Buyer's Directory.

THE DISEASES OF ELECTRICAL MACHINERY. By Ernst Schulz. Edited with a preface by Silvanus P. Thompson. 94 pages, 42 illustrations. 12mo., cloth. Price, $1.00. London: E. & F. N. Spon. New York: Spon & Chamberlain. 1904.

CONTENTS.—Chapter I.—Continuous Current Machines. II.—Single-phase and Polyphase Generators. III.—Single-Phase and Polyphase Induction Motors. IV.—Transformers. V.—Efficiency.

SMOLEY'S PARALLEL TABLES OF LOGARITHMS AND SQUARES. Angles and Logarithmic Functions, Corresponding to given Bevels, and other Tables. By Constantine Smoley, C.E. Fourth revised edition. 331 pages. New York: The Engineering News Publishing Company. Price, $3.00.

CONTENTS.—Parallel Tables of Logarithms and Squares. Tables of Angles and Logarithmic Functions. Table of Logarithms of Numbers. Decimal Equivalents. Constants. Explanations and Examples.

THE BLOCK SYSTEM OF SIGNALING ON AMERICAN RAILROADS. By Braman B. Adams. 234 pages. Illustrated. New York: The Railroad Gazette. 1901. Price, $2.00.

CONTENTS.—Chapter I.—The Telegraph Block System. Pennsylvania R.R. II.—The Telegraph Block System—Continued—Erie R.R., Chicago, Burlington & Quincy R.R. III.—The Telegraph Block System on Single Track—Chicago, Milwaukee & St. Paul Ry. IV.—Single-Track Blocking—Continued—Erie R.R.; Wabash R R ; Atchison, Topeka & Santa Fe Ry. V.—The Controlled Manual or "Lock and Block" System. New York, New Haven & Hartford R.R. VI.—Controlled Manual—Continued; The Electric Train Staff. VII.—Automatic Block Signals—Clock-work Apparatus; Enclosed Disk Signals. VIII.—Automatic Block Signals on Single Track —Cincinnati, New Orleans & Texas Pacific Ry. IX.—Electro-Pneumatic Automatic Block Signals. X.—Automatic Block Signals. The Electric Semaphore. XI.—Three-Position Automatic Block Signals—Pittsburgh, Fort Wayne & Chicago Ry. XII.—Conclusions; Statistics. XIII.—The Saxby & Farmer Interlocking Machine. XIV.—The Johnson Interlocking Machine. XV.—The Westinghouse Electro-Pneumatic Machine. XVI. The Low Pressure Pneumatic Machine. XVII.—The Taylor Electric Machine.

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Name and when Organized.	Chairman.	Secretary.	Regular Meeting.
SECTIONS.			
Atlanta............Jan. 19, '04	A. M. Schoen.	W. R. Collier.	
Baltimore.........Dec. 16, '04	J. B. Whitehead.	C. G. Edwards.	2d Friday.
Boston............Feb. 13, '03	Wm. L. Puffer.	C. H. Tapping.	3d Wednesday
Chicago...............1893	H. R. King.	J. G. Wray.	1st Tuesday after N. Y. meeting.
Cincinnati.........Dec. 17, '02	A. G. Wessling.	A. C. Lanier.	
Cleveland.........Sept. 27, '07	Henry B. Dates.	F. M. Hibben.	3d Monday.
Columbus.........Dec. 20, '03	R. J. Feather.	H. L. Backman.	1st Monday.
Minnesota..........Apr. 7, '02	H. J. Gille.	Barry Dibble.	2d Monday after N. Y meeting.
Pittsburg..........Oct. 13, '02	C. E. Skinner.	R. A. L. Snyder.	1st Wednesday.
Pittsfield..........Mar. 25, '04	J. Insull.	H. L. Smith.	3d Thursday.
Philadelphia.......Feb. 18, '03	J. F. Stevens.	H. F. Sanville.	2d Monday.
San Francisco......Dec. 23, '04	C. L. Cory.	A. H. Babcock.	
Schenectady.......Jan. 26, '03	D. B. Rushmore.	W. C. Andrews.	Every Friday.
Seattle............Jan. 19, '04	C. E. Magnusson.	W. S. Wheeler.	3d Saturday.
St. Louis..........Jan. 14, '03	A. S. Langsdorf.	H. I. Finch.	2d Wednesday.
Toledo............ June 3, '07	W. G. Nagel.	Geo. E. Kirk.	1st Friday.
Toronto..........Sept. 30, '03	K. L. Aitken.	L. W. Pratt.	2d Friday.
Urbana...........Nov. 25, '02	J. M. Bryant.	E. B. Paine.	1st Wednesday after N.Y. meeting.
Washington, D. C..Apr. 9, '03.	P. G. Burton.	Philander Betts.	1st Thursday.
BRANCHES.			
Armour Institute...Feb 26, '04	T. C. Oehne, Jr.	J. E. Snow.	1st & 3rd Thursdays
Cornell University..Oct. 15, '02	E. L. Nichols.	H. H. Norris.	1st Friday after N. Y. meeting.
Iowa State College..Apr. 15, '03	F. A. Fish.	Adolph Shane.	1st Wednesday.
Lehigh University..Oct. 15, '02	A. W. Lawson.	M. T. Saldana.	3d Thursday
Montana Agr. Col..May 21, '07	C. M. Fisher.	J. A. Thaler.	1st Friday.
Ohio State Univ....Dec 20, '02	H. C. Bartholomew	F. E. Beutler	Every Tuesday evening
Penn. State College.Dec 20, '02	E. W. Nick.	S. W. Price.	Every Wednesday
Purdue University..Jan. 26, '03	J. W. Esterline.	H. T. Plumb.	Every Tuesday.
Syracuse University Feb. 24, '05	W. P. Graham	R. A. Porter.	1st and 3d Thursdays.
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PROCEEDINGS

OF THE

American Institute

OF

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President's Address A. S. M. E.

WHILE this issue is on the press, the annual meeting of the American Society of Mechanical Engineers is being held in the Auditorium of the Engineers' Building. The address of President Hutton at the opening session, Tuesday evening, December 3, was entitled " The Mechanical Engineer and the Function of the Engineering Society ". The twenty-three years' experience of the author as secretary of the American Society, followed by a year in the presidential chair, has thoroughly qualified him to discuss the various functions of a national engineering organization. The first portion of his address is devoted to specialization in engineering in which he enumerates thirteen different branches which are usually considered as being the more important. No doubt his definitions will in many instances be criticized, yet the classification has been so carefully worked out, and is so comprehensive, that it will be exceedingly valuable as a guide to those who are in doubt as to the requirements of an " engineer ". When we consider the doubts existing twenty-five years ago as to the status of the electrical engineer, it is certainly encouraging to read the closing sentence of the definition of the profession: " His field is very definite ". In his arguments for the appreciation of a national engineering organization, President Hutton shows most emphatically the thoughtful care he has bestowed upon the duties of the office he held so creditably for nearly a quarter century. How to make the society of the greatest value to the membership was the problem continually before him. Equally urgent was the task of convincing the non-member that even from a selfish standpoint it was his duty to join. He might well have added that to be considered a responsible mechanical engineer his name must be found in the official catalogue. Among other functions of the society treated in this admirable address, are the location and composition of conventions, technical visits, publications and the valuable work of committees. He does not look for successful local meetings confined to members, but proposes a plan for independent self-governing sections, which shall be affiliated with the American Society of Mechanical Engineers, to which non-members shall be eligible, upon a plan very similar to that which has been in practical operation in the Schenectady Section of the Institute. While President Hutton's address was prepared with special reference to mechanical engineers, it is of general interest to the entire engineering profession, and all who are actively engaged in society work will find it exceedingly instructive.

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Twenty-five Years of Institute History *

In view of the fact that according to the printed records of the Institute, the first steps towards its formation were taken in April, 1884, it may seem premature for me to-night to talk even twenty-five minutes about twenty-five years. But we are on the verge of 1908, and the Institute was already in existence in the minds of its advocates and friends in 1883, long before we circulated for signature the "call to arms" now hanging on the walls of the headquarters in the beautiful new home on Thirty-ninth street, New York. I had the honor to assist Dr. N. S. Keith in the preparation of the famous April circular and to secure many of the notable signatures to it. It fell equally to my lot to prepare and issue the first volume of TRANSACTIONS and to make the first secretarial report. I have never enjoyed the confidence of the Institute sufficiently to be trusted as its treasurer, but I have been elected to every other office in its gift and may therefore venture to discuss it, on your invitation, from the inside and its various other aspects.

A good many of us in the electrical field—over 5000 now in membership—are interested in the Institute's welfare, and to us the story of its trials and struggles and evolution is not altogether vain and insipid. History repeats itself, and probably the growth of every engineering and scientific society follows much the same course. Electrical engineers came pretty late in the procession, but after all are not in a class by themselves. Scientific and engineering bodies are ancient rather than modern inventions. A young mother whose infant was ailing went to an old-fashioned doctor and asked for treatment. He prescribed castor oil. "But doctor", she exclaimed, "castor oil is such an old-fashioned remedy". "Madam", replied the doctor dryly, "babies are such old-fashioned things".

No one will deny to the Institute, however, characteristics and idiosyncrasies due to the circumstances of its birth and to the development of the mighty agencies included under the generic name of electricity. There may be, and I trust there is, something personal in the feeling that the make-up of the Institute has a youthfulness and vivacity about it that the other kindred societies do not all possess. I was only thirty myself when elected to the presidency, and while some of my successors, down to this very year, have been dangerously near that age, I am told that in other societies such juvenility in high office would be regarded as scandalous. It seems likely that amongst the electrical engineers, youth will not yet be a bar to the supreme dignities. A notable orator in speaking about the late Mr. James G. Blaine, said that his magnetism had to be taken hot or else it soured on the stomach. It is certain that the Institute has rarely had its electricity or magnetism served up on cold plates. I know of one president who never attended a single meeting, but his contribution to the art and to mankind would condone vastly greater indifference, just as the verse of Burns, a tender boon to all humanity, has won pardon for the shortcomings of his brief, chequered life.

Speaking as the senior surviving president of the Institute, it might be expected that I should make some allusion to the nineteen men who have held the office since the beginning in 1884. How some persons get elected to presidential office is a mystery, even granting their great individual qualifications; and it is equally strange how others miss the distinction. It does not follow that because a man is a great engineer or inventor he has the executive ability for leadership; and moreover he may be right in shunning instinctively that which would only be a distraction from his true work. Two of our most distin-

* A paper read by Past-president T. Commerford Martin at a meeting of the Schenectady Section November, 1907.

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guished members, known throughout the world, have not accepted this office; yet it is surely a matter for congratulation that of the nineteen men no fewer than fifteen have been engineers very distinctively, and the names of seventeen are attached to inventions some of which are the greatest of the last fifty years. This is a large proportion, particularly when it is borne in mind that no fewer than eight of the nineteen have followed the profession of teacher, and three others have been journalists, who speak not as those having authority but as mere scribes. Perhaps the most striking fact about the list and the testimony it bears to the catholicity of the American engineering spirit as well as the manner in which our national strength is reinforced—is that seven of the nineteen, including the present incumbent, were not natives of this country. The career open to talent that was regarded by Napoleon as such a desideratum, is obviously to be found in this country as nowhere else in the world.

Somehow the method of electing our presidents has never yet been all that we could wish, although the results have been highly satisfactory. Where there is high office at stake, possibly there must also be the appeal to laudable ambition or the play of contending forces; but whatever will lessen rather than inflame antagonism is to be sought and should be our ideal. As a matter of fact, a clean, healthy struggle does much to stimulate interest in the welfare of the body; but that which leaves bitterness behind and involves misunderstanding and estrangement between good men and quondam friends is simply deplorable in the last degree. However, as the Institute is a "pure democracy" of pronounced type, the ills of democratic life must be accepted with the benefits; and the great fact remains that our highest award of recognition for public service or intellectual achievement never stood in more honored estimation of the membership than it does to-day.

For a while the presidency of the Institute was liable to be a two-year term, since changed by constitutional amendment, providing for a steady annual rotation in office. Both methods have their advantages, but with so liberal an amount of good presidential timber in the Institute it would really have been a pity to adhere to a process that slowed down promotion. It is claimed that a longer term ensures permanence to a policy; but on the other hand the plan of continuing a past-president on the Board of Directors gives him a fair chance to carry out any pet scheme. The one year term brings variety and freshness to the front and ever a new way of looking at things. Of course there is some danger that a fad may be run pretty hard, but on all great questions there is the appeal to the sober sense of the Institute. This president may be keen on standards, the next on membership, a third on the quality of the papers. One is in favor of a policy of rapid expansion; the next does some bookkeeping and pays the bills.

I have spoken of the automatic regulation of all this by council and membership, but there is still another power behind the throne. A vivacious young American lady staying at an English country house was devoting her attention at dinner much more to the neighbor on the right than to the lonesome one on the other side. This bothered the good old family butler, and while handing a dish he managed to whisper very respectfully in her ear: "A little more conversation to the left, miss". In like manner, our amiable and worthy secretary, guiding successive presidents, has doubtless with his suave diplomacy many a time intimated quietly that the best interests of the Institute demanded that all its agencies should be cut in and run in parallel, and "with a little more conversation to the left".

In truth, influential and powerful as the president is under our Constitution, he is necessarily like the Institute itself,

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very much at the mercy of the secretary. To a certain extent the overlapping time classes in the Board of Directors give, as intended, continuity of experience and tradition, but the personal depository of knowledge and the confidential adviser in all such bodies must always be the man who occupies the secretaryship. It is a singular fact that in three of our great national engineering societies, the secretary should have held office without break for nearly a quarter of a century; and in the Institute, with its rapid growth, swift changes in the art, and perennially new problems, we were fortunate to secure a man like Mr. Ralph Pope, who is still there and whose worth was publicly recognized this year by the bestowal of a gold medal at the dedication of the Engineers' Building.

Dr. Keith, with whom in 1883–4 I got up and circulated the petition for the creation of the Institute, went West almost immediately after the first meeting, and I was left in charge as a stopgap secretary. The activity in electrical development at that time was so tremendous that I found I could not do justice to my regular journalistic work and to the Institute's affairs at the same time. It was a providential dispensation which gave us at that juncture Mr. Pope's services, for with instant sympathy he took up the work of development that has gone on without cessation to the present moment. Unhasting and unresting, of him it cannot be said that anybody ever saw him in a hurry; but the work has always got done. The possession of the lymphatic temperament is, as in him, sometimes associated with a remarkable ability to accomplish. A few years ago, the pastor of a leading New York church died, whereupon having in mind his virtues and labors the vestrymen put up a tablet on the walls with this quotation: "Now the people of God have rest ". I can well imagine that when some administrations have faded into the background, our good secretary had felt like emulating the example of that vestry, for he has never fallen into the error of mistaking restlessness for achievement. Disraeli once compared his Liberal opponents to little children pulling up their plants every morning to see how much they had grown in the night. From such practice the conservatism of our secretary has always saved us, and we have had the growth just the same and all the more. His first report presented in May, 1886, showed a net total of 250 members. We now have over 5,000, not including Students, so that our membership has multiplied twenty times in the period. The average budget was then less than $1,000.00. It is now $70,000.00. Granting the tremendous development in our field of engineering, it remains evident that only conscientious care and a thorough grasp of the situation could have brought us through all these years to the firm, stable, and prosperous position we now hold.

Comparisons were long since given a bad name, but it is only by noting the progress of other societies that we can realize how far and fast our own Institute has travelled. In the year when the American Institute of Electrical Engineers was organized, 1884, the American Society of Civil Engineers had 838 members. At the beginning of this October, it had 4,287, and by the end of the year will have 4,400. In 1884, the American Institute of Mining Engineers had 1,381 members; on October 5 it had 4,179. At the close of 1884, the American Society of Mechanical Engineers had 557 members and on October 1 it had 3,335 members. Hence in spite of their flying start and time allowance, the American Institute of Electrical Engineers has outrun all the other societies, and with its 5,000 members is distinctly in the lead. I don't know that there is any special credit in this; it is simply a fact worth noting; it may carry an implication or prophecy as to relative numerical importance later on. The growth of these

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sister societies is reason for hearty congratulation all around. The enrolment in four national technical bodies of nearly 17,000 professional members is surely an indication of the growing influence of engineers and engineering in a civilization that they at least as much as any other factor have created.

Throughout the career of the Institute I have been constantly impressed with the evolutional nature of its growth. What I mean is that at the very outset certain elements and essentials were set forth as desirable, and that persistently, if unconsciously, the society had pursued the ideals of the founders. A perusal of the earliest volumes of TRANSACTIONS shows emphasis to have been laid on a library, a permanent home, branches or chapters; raising the character and qualifications of membership; standardization of apparatus and tests; securing papers on the latest advances and from representative men; the interchange of courtesies with domestic and foreign societies. Some of these points may be fittingly noted as having been attained much more fully and richly than the idealists and prophets of 1884 deemed possible. In this country "the greater lies before" always, but it is very hard to determine the lines of growth in advance. According to the poet Coleridge, the path that human beings love to tread is a winding one—"around the corn fields and the hill of vines"—and even in America with our direct methods, short cuts, and ruthless disregard of conventional processes, we exemplify rarely the Euclidian definition of a straight line. Yet the Institute has been singularly happy in developing to fruition in its first twenty-five years so many of the propositions that it dedicated to the benefit of mankind when it started.

Think of the dignified and graceful home occupied as headquarters in New York, said by an English architect of repute to be of all the buildings he saw in America the best adapted to its purpose. We were homeless cuckoos when we began, meeting here and there, enjoying the hospitality of other societies, like the civils and mechanicals, changing our offices eight times in only twenty years, and living from hand to mouth in a manner utterly beneath the status and requirements of a great Institute. The first evidence of nationality is a permanent seat of government, and I for one should have regarded it as a misfortune had the Institute twenty-five years old still been without a definite centre, a house and a hearth, a worthy focus for all its activities, and a proper organ for the exercise of all its functions. Of course it is true that the essence of a real living Institute does not lie in bricks and mortar. It was said once that a certain famous man at the end of a log and a student at the other end would constitute a university; but all students know full well that learning must have its endowments, its faculties, its libraries, its laboratories, even its chapels, its stately halls, and its physical housing of every kind. Some fine natures shrink from this realistic clothing of their hopes and ideals, but it is a far deeper and truer instinct that demands the concrete accomplishment. Every real man wants a home.

At any rate, the Institute has answered forever, in satisfactory fashion, the question "Why pay rent?" and is now dealing vigorously with the problem "Why stay in debt?" I am rather proud, though not vainglorious, of the fact that your Land and Building Fund Committee, of which I have the honor to be chairman, has raised in three years from about 1,000 members and friends, the handsome sum of $160,000, nearly all of which is paid in. It hopes to close its debt-lifting campaign this winter by getting the $20,000 still needed. The committee has now and again met with discouragement and disappointment in some quarters where it had high hopes, but will not relinquish its efforts, till the work is done. It believes that the public spirit and active good-will of the

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4,000 members who have still to subscribe will soon free the Institute from all this burden, leaving it with an asset of rapidly increasing value and with all its agencies in unhampered full play.

The joint library in the new Engineers' Building given us by Mr. Carnegie is one of the best evidences of the good that flows already from the creation of the new home. There we have what is probably, even now in the earlier stages of organization, the best collection of engineering literature in the world. It is constantly securing valuable accessions, and students more and more frequent it. Together with the grand public library on the next street, now being finished, it will constitute the best centre of scientific and literary investigation, through the printed word, to be found on this continent. When our past president, Dr. Wheeler, with generous impulse, gave us the Latimer Clark library, he little thought that from such a nucleus, or so soon, would come in reality, both the building and the splendid larger library it now enshrines. We electricals are, indeed, not as appreciative as we ought to be of what has come through Dr. Wheeler's initiative and liberal gift —a critical event in Institute history, determining all the future.

There has been in some minds the haunting fear that this building and all that it represents, would make for centralization in the society, for an undue accumulation of power in New York hands; but it is a noteworthy fact that never before was the establishment of Sections and Branches carried on so strenuously. Moreover, men who have been prominent in the erection of the building have been most earnest advocates of this policy of decentralization, and past-president Scott, one of the foremost in our building work, was as a matter of fact the father of the modern movement that has brought into being such wonderfully successful local bodies as your own, whose usefulness it is indeed hard to compute fully. But if you will go back into the annals and archives you will find that others of us years ago were strong federalists and at the Institute meetings favored policies aiming at the principles approved in the latter days. The vigor of the Sections and Branches is cause for profound congratulation, the best proof of health; and a pledge of universal interest amongst widely scattered members of the profession, in the work of the Institute.

It would be simply impossible here to review the papers and TRANSACTIONS of the Institute during twenty odd years. A long serried row of 25 substantial volumes, containing 16,000 pages of printed matter looks at me from my book shelves as I prepare these notes, and picking out any one of them I find valuable fact and data, theory and speculation, from scores of members. It might all have been done better —I know that, from serving years as the chairman of the committee on papers and meetings—but it was something to put into such permanent and readily available form that mass of useful material. As one surveys the great throbbing, productive domain of electricity, it seems easy to get all the papers you want, from anybody you choose, but the exact contrary is the fact. I am not ashamed to-day that my own paper and statistics on electric railway work in 1886 was the first of the kind in America, but the literal truth is I was just a stage manager called upon to fill a leading rôle suddenly because the chief actor in the cast was sick. Thus are honors thrust upon us, —and more than once I have said to other chairmen left in the lurch: "Get up a paper yourself to fill the gap". What we really need is a higher sense of responsibility toward the Institute amongst all members, so that whatever the press may publish, our TRANSACTIONS shall always have the definite complete record of a *fait accompli*. One way of getting that result is to have yearly reviews of work in each field, but such performances tend to become hackneyed. to lack real vitality, and

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to load the TRANSACTIONS. In reality one of the dangers lies in the natural desire of a new president or chairman to have his volume of TRANSACTIONS a little fatter in sheer bulk than that of his predecessor. Such megalomania is mild and harmless, but often costly in printers' bills. Probably there will never be a time when part of the TRANSACTIONS could not be omitted with real gain; but the chairman on papers has a hard time and must be forgiven if his efforts to get the best do not always reach the maximum result. Besides, as the years go by, much that is in the volumes and once was timely loses its sap and savor of the moment through nobody's fault. Even in a scientific engineering body we are swayed by winds of doctrine or moved by fancies and phases, and the papers committee is most likely to draw contented audiences when it can promise startling topics and the star performer of the hour.

One of the most agreeable features of the Institute development has been the interchange of courtesies with kindred societies abroad. We all know the kind of wits attributed to homekeeping youth, and even learned bodies are found to benefit by a sea change. We may yet live to see the Royal Society meeting in Chicago; the French Academy in session at Montreal; and in these days of politics more villainous than saltpetre, let me express the hope that some early day the American Institute of Electrical Engineers will hold its annual meeting in friendly Tokio, when the cherry trees are all ablossom. Meanwhile we have had the privilege to entertain in the land of Franklin, the fellow countrymen of Faraday and Volta, of Ampere and of Ohm; and they too have made us welcome in return. I feel confident that in time, this closer touch must lead to more intimate union; and that in engineering solidarity we shall find one more pledge and guarantee of the peace of the world. The aptest synonym for engineering is association.

To make laws is a confession of human weakness. But the desire to legislate for fellow men springs ever in our breasts. The Institute has found abundant occupation in standardization of material, and more latterly has branched off into the standardization of morals. In all this, only commendation can follow, but there always lurks the peril of petrifaction.

Our little systems have their day;
They have their day and cease to be:
They are but broken lights of Thee,
And Thou, O'Lord, art more than they.

No standardization must be final; it is only a basis for new departure if it is worth anything. Of all others, the electrical arts are to-day most in a state of flux and transition, and the bondage of prescription cannot be laid upon them. The greater the number of conditions we agree upon, the larger should be the freedom for all else.

Codes of ethics are the latest efforts at standardization to occupy our thoughts in the Institute. It is a sign of the times, an admission on the part of the individual that before he flays alive a corporation he ought to examine his own credentials as executioner. We must of course all be in sympathy with the effort to secure affirmation for such a code as is proposed for the Institute, but no virtue of purity or salvation lies in the code itself. It is a mere formula of words and phrases. The moral law has never been observed by a single human being since it was given shape, yet the world has steadily grown better through the unconscious striving of our race upward and onward. Codes of ethics are besprinkled thickly through the ages; declarations of faith and fervor come into political platforms once a year; and the man who when asked to sign the Thirty-nine articles regretted there were not forty does not stand unique. By all means let us have a code, but do not let us expect too much of it. Not long ago a Northerner went into a Southern village store and asked for a pair of socks, size No. 10. The storekeeper was sorry, but he kept only

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one size, No. 12. "Why", said the astonished Northerner, "surely you don't mean to say that every man and boy in this village wears the same size sock"? "Oh! no", was the cheerful, ready answer, "but if the socks happen to be too long they pulls 'em up at the heels, and if they are too short they tugs 'em down at the toes". It is thus with all codes made like ancient torture beds, to fit all cases and all men.

I find myself wandering from history into metaphysics, but a past-president has possibly some license, because he is supposed to have been reduced to an innocuous condition. I seem to have covered a good many topics, but all I will ask you to credit me with is a desire to express my attachment to the Institute and an ambition to stimulate in the younger members a zeal and enthusiasm far greater than I have been able to show these twenty-five years.

Applications for Election.

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the Secretary before January 10, 1908.

6888 D. C. Durland, New York City.
6889 Walton Clark, Philadelphia, Pa.
6890 J. F. D. Hoge, New York City.
6891 C. A. Kelsey, Pittsfield, Mass.
6892 J. H. Poats, Baltimore, Md.
6893 Hartley Rowe, Canal Zone, R. de P.
6894 C. B. Mirick, Washington, D. C.
6895 T. H. McCauley, Port Arthur, Ont.
6896 J. C. Peet, Rochester, N. Y.
6897 P. C. Schools, Burke, Idaho.
6898 J. E. Smith, Washington, D. C.
6899 H. W. Carey, Ithaca, N. Y.
6900 Eli Clemens, Gary, W. Va.
6901 G. C. Ellett, Puebla, Mex.
6902 George Howe, Mexico City, Mex.
6903 W. J. Jordan, Los Angeles, Cal.
6904 C. H. Hughes, Mexico City, Mex.
6905 G. S. Johnson, Berkeley, Cal.
6906 Emil Leonarz, Mexico City, Mex.
6907 H. R. D. de Sinclair, Newark, N. J.
6908 E. W. Scherr, Jr., New York City.
6909 M. S. Towson, Cleveland, O.
6910 E. D. Ward, Arlington, N. J.
6911 L. W. Brownrigg, New York City.
6912 T. R. Bremner, Mexico City, Mex.
6913 J. E. Couch, Dallas, Texas.
6914 Julius Hermann, Mexico City, Mex.
6915 T. H. Seaver, Mexico City, Mex.
6916 C. A. Bixby, Schenectady, N. Y.
6917 E. S. Fletcher, Temple, Texas.
6918 W. E. Ketcham, Yokohama, Japan
6919 H. A. Tedman, Chicago, Ill.
6920 T. W. Winsor, Napa, Cal.
6921 E. W. Cutler, Chicago, Ill.
6922 Hugh Fitzhugh, Tuscaloosa, Ala

Total, 35.

January Meeting

At the meeting on January 10, 1908, there will be papers on single-phase distribution, by W. S. Murray, electrical engineer of New York, New Haven and Hartford Railroad; also a paper on "A New Single-phase Railway Motor", by Ernst Alexanderson, electrical engineer, General Electric Co., Schenectady.

Annual Convention

The Institute has not yet decided where to hold the next annual convention. Suggestions for a place of meeting will be received by the secretary and transmitted to the convention committee.

Year-Book

THE catalogue contained in this issue is also printed in a recently published year-book which includes the Standardization Rules and the Constitution. As the entire contents of the year-book have appeared in the PROCEEDINGS, copies have not been supplied to the membership at large and the volume is being used principally in connection with the work of the Increase of Membership Committee. Any Member or Associate may, however, obtain a copy upon request by mail or in person.

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

CATALOGUE OF MEMBERS.

AUGUST 1ST, 1907.

HONORARY MEMBERS.

Name and Address.	Date of Membership.
KELVIN, *Lord, D.C.L., LL.D., F.R.S.* 15 Eaton Place, London, S. W., England.	H.M. May 17, 1892
PREECE, *Sir* WILLIAM H., *K.C.B., F.R.S.*, Consulting Electrical Engineer, 13 Queen Anne's Gate, London, S. W., Eng.	H.M. Oct. 21, 1884

Honorary Members, 2.

MEMBERS.

Name and Address.	Date of Election and Transfer.
ACHESON, EDW. G., President, The Carborundum Co., Niagara Falls, N. Y.	A Jan. 3, 1888 M May 1, 1888
ADAMS, ALTON D., Consulting Engineer, State Mutual Building, Worcester, Mass.	A Apr. 18, 1893 M Jan. 17, 1894
ADAMS, COMFORT A., Prof. Electrical Engineering, Harvard University, Cambridge, Mass	A Jan. 17, 1894 M Feb. 24, 1905
AHEARN, THOMAS, Ahearn & Soper, Electrical Supplies, Ottawa, Ont.	A July 12, 1887 M Sep. 6, 1887
ALBANESE, G SACCO, Engineer, 7 rue Saulnier, Paris, France.	A Sep. 20, 1893 M Sep. 27, 1899
ALBRIGHT, H. FLEETWOOD, Electrical Engineer, Western Electric Co., 463 West St., New York City.	A Sept. 27, 1892 M June 20, 1894
ALDRICH, WILLIAM S., Director, Thomas S. Clarkson [Life Member.] Memorial School, Potsdam, N. Y.	A Mar. 15, 1892 M Apr. 25, 1900
ANDREWS, WILLIAM S., Manager Central Station Sales, General Electric Co., Schenectady, N. Y.	A Mar. 5, 1889 M Apr. 22, 1896
ANSON, FRANKLIN ROBERT, 52 Broadway, New York City.	A Feb. 27, 1895 M Nov. 23, 1898
ANTHONY, WILLIAM A., [*Past-President*] Consulting Electrician, Cooper Union, New York City.	A Dec. 9, 1884 M Jan. 6, 1885
ARMSTRONG, ALBERT H. [*Vice-President*], Electrical Engineer, General Electric Co., Schenectady, N. Y.	A June 24, 1898 M Feb. 26, 1904
ARMSTRONG, CHAS. G., Consulting Electrical Engineer, 17 Battery Place, New York City.	A Sept. 27, 1892 M Aug. 31, 1898
ARNOLD, BION J. [*Past-President*], Consulting Electrical Engineer, Borland Bldg., Chicago, Ill.	A Oct. 25, 1892 M Nov. 15, 1893
ATKINSON, WILLARD S., Supervising Engineer, University Power Co., Princeton, N. J.	A Oct. 25, 1901 M Jan. 23, 1903

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AYER, JAMES I., General Manager American Electric Heating Corporation, Cambridge, Mass.	A May 19, 1891 M Apr. 19, 1892
BABCOCK, ALLEN HARWOOD [*Local Secretary*], Electrical Eng., S.P. Co., Flood Bldg., San Francisco, Cal.	A Mar. 25, 1904 M Oct. 26, 1906
BADT, FRANCIS B., Electrical Engineer, F. B Badt. & Co., 1504 Monadnock Block, Chicago, Ill.	A Apr. 19, 1892 M Mar. 25, 1896
BAILLARD, E. V., Manufacturer of Electrical Instruments, 24 Frankfort St., New York City.	A Dec. 3, 1889 M Jan. 16, 1895
BALDWIN, BERT L., Mechanical Engineer, Perin Building, Cincinnati, O.	A Apr. 22, 1896 M Nov. 18, 1896
BANCROFT, CHAS. F., Electrical Engineer, Massachusetts Electric Cos., 84 State St., Boston, Mass. [Life Member]	A Dec. 18, 1895 M Apr. 27, 1906
BARBOUR, FRED FISKE, Manager, Sales Dept. Pacific Dist., G.E.Co., Oakland, Cal.	A May 16, 1893 M Sep. 26, 1900
BARCLAY, JOHN C., Asst. General Manager, Western Union Tel. Co., 195 Broadway, New York City.	A Apr. 23, 1903 M June 15, 1904
BARNES, HOWEL H. JR. Consulting Engineer, General Electric Co., 44 Broad St., New York City.	A Feb. 28, 1900 M Aug. 17, 1904
BARSTOW, WILLIAM S., Consulting Electrical and Mechanical Engineer, 50 Pine St, New York City.	A Feb. 21, 1894 M Apr. 26, 1899
BARTON, PHILIP PRICE, General Manager, N. F. P. Co. & Can. Niagara P. Co., Niagara Falls, N. Y.	A July 12, 1900 M June 28, 1901
BATCHELOR, CHAS., Electrical Engineer, Exchange Court Bldg., 52 Broadway, New York City.	A June 8, 1887 M July 12, 1887
BATES, JAMES H., *M.E.*, Consulting Engineer with Viele, Cooper & Blackwell, New York City.	A Sep. 6, 1887 M Oct. 1, 1889
BAUM, FRANK GEORGE [*Vice-President*], Consulting Engineer, 1405 Chronicle Bldg., San Francisco, Cal.	A Nov. 22, 1899 M Oct. 27, 1950
BAYLIS, ROBERT NELSON, The Baylis Co., 140 Washington St., New York City.	A Oct. 1, 1889 M May 17, 1892
BEAMES, CLARE F. [*Local Hon. Secretary*], Manager, San Juan Light & Transit Co., San Juan, P. R.	A May 21, 1895 M Feb. 28, 1901
BECHTEL, ERNEST J., Electrical Engineer, The Toledo Railways and Light Company, Toledo, O.	A Mar. 24, 1897 M July 27, 1900
BEDELL, FREDERICK, Professor of Applied Electricity, Cornell University, Ithaca, N. Y.	A Apr. 21, 1891 M May 19, 1896
BEHREND, BERNHARD ARTHUR, Chief Engineer, Bullock Electric Mfg. Co., Cincinnati, O.	A Jan. 24, 1900 M Sep. 26, 1902
BELL, ALEXANDER GRAHAM [*Past-President*], 1331 Conn. Ave., Washington, D. C., and Baddeck, N. S.	A Apr. 15, 1884 M Oct. 21, 1884
BELL, LOUIS, *Ph.D.* Consulting Electrical Engineer, 120 Boylston St., Boston, Mass.	A May 20, 1890 M June 18, 1890
BENECKE, ADELBERT O., Consulting Electrical Engineer, 19 Arlington Ave., Vailsburgh, N. J.	A Sep. 26, 1902 M Oct. 27, 1905
BENEDICT, HERSCHEL A., Electrical Engineer, United Traction Co.; res. 129 Western Ave., Albany, N.Y.	A Oct. 27, 1905 M Feb. 23, 1906
BERG, ERNST JULIUS, Engineer, General Electric Co., Schenectady, N. Y.	A Sep. 19, 1894 M July 25, 1902
BERNARD, EDGAR G., Manufacturer, 450 Fulton St., Troy, N. Y.	A Jan. 5, 1886 M July 12, 1887
BERRESFORD, ARTHUR W., *B.S., M.E.*, Supt. Cutler-Hammer Mfg. Co., Milwaukee, Wis.	A May 15, 1894 M Oct. 26, 1906
BETTS, PHILANDER, [*Local Secretary*] Electrical Engineer, Potomac Power Co., Washington, D. C.	A Mar. 25, 1896 M Jan. 25, 1899

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BILLBERG, C. O. C., Electrical Engineer, 3311 Walnut St., Philadelphia, Pa.	A Mar. 21, 1894 M Feb. 27, 1895
BILLINGS, ASA WHITE KENNEY, Consulting Engineer, Empedrado 30, Havana, Cuba.	A Mar. 1, 1907 M July 26, 1907
BLACKWELL, FRANCIS O., Consulting Engineer, Room 605, 49 Wall St., New York City.	A Mar. 28, 1900 M Dec. 18, 1903
BLADES, HARRY H., Electrical Engineer, Alexandria, Minn.	A April 19, 1892 M May 21, 1895
BLAKE, FRANCIS, Auburndale, Mass.	A Sep. 3, 1889 M Oct. 1, 1889
BLOOD, JOHN BALCH, Blood and Hale, Consulting Engineers, 10 Post Office Square, Boston, Mass.	A June 20, 1894 M Dec. 18, 1895
BLOOD, WILLIAM HENRY, JR., Stone & Webster, Eng'g Corporation, 84 State St., Boston, Mass.	A July 28, 1905 M Feb. 23, 1906
BLUNT, WILLIAM W., Assistant Manager, Br. W. E. & M. Co., Ltd., Westinghouse Bldg., London, Eng.	A Dec. 16, 1896 M July 26, 1907
BOGGS, LEMUEL STEARNS, Westinghouse E. & M. Co., 315 Lucas Building, Mt. Vernon, N. Y.	A Sep. 20, 1893 M May 17, 1898
BOILEAU, WILLARD E., Engineer, N. Y., Westchester & Boston Rwy. Co., 37 Wall St., New York City.	A Sep. 19, 1894 M Mar. 25, 1896
BOSCH, ADAM, Superintendent Fire Alarm Telegraph, Newark, N. J.	A Apr. 15, 1884 M Jan. 6, 1885
BOTTOMLEY, HARRY, General Supt., Fall River Electric Light Co., Fall River, Mass.	A Apr. 2, 1889 M Jan. 22, 1896
BOURNE, FRANK, Consulting Engineer, 62 London Wall, E. C., Eng.	A Apr. 21, 1891 M Nov. 15, 1892
BOYER, ELMER E., Foreman, Testing Department, Lynn Works, General Electric Co., Lynn, Mass.	A Sep. 25, 1895 M Mar. 25, 1896
BOYNTON, EDWARD C., Electrical Engineer, Newburg, N. Y.	A Aug. 6, 1889 M Nov. 24, 1891
BRADLEY, CHAS. SCHENCK, President, Atmospheric Products Co., 41 Park Row, New York City.	A May 24, 1887 M Dec. 6, 1887
BRADY, FRANK W., *M.E.*, Engineering Text Book Writer, International Corr. Schools, Scranton, Pa.	A June 20, 1894 M Mar. 28, 1900
BRENNER, WILLIAM H., Manager, The Zemma Works, Isogo Mura, Yokohama, Japan.	A Sep. 20, 1893 M Mar. 21, 1894
BRINCKERHOFF, HENRY MORTON, with Wm. Barclay Parsons, 60 Wall Street, New York City.	A Sep. 23, 1896 M Dec. 16, 1896
BRISTOL, WILLIAM HENRY, Professor of Mathematics and Mechanics, Stevens Institute, Hoboken, N.J.	A Nov. 23, 1906 M Jan. 25, 1907
BROOKS, MORGAN [*Manager*], Prof. Electrical Engineering, Univ. of Illinois, Urbana, Ill.	A May 20, 1890 M June 17, 1890
BROWN, J. STANFORD, *E.E.*, President, Realty Loan [Life Member.] Trust Co., 489 5th Ave., New York.	A Sep. 6, 1887 M Nov. 1, 1887
BROWNE, ROBERT JAMIESON, Electrical Engineer, Bengal Command, Hastings St., Calcutta, India.	A Dec. 23, 1904 M Oct. 27, 1905
BROWNE, SIDNEY HAND, American Telephone & Telegraph Co., 125 Milk St., Boston, Mass.	A Apr. 28, 1897 M Nov. 23, 1898
BRUSH, CHAS. F., Electrical Engineer, 453 The Arcade, Cleveland, O.	A Apr. 15, 1884 M Oct. 21, 1884
BUCK, HAROLD W. [*Manager*], Electrical Engineer, 49 Wall St., New York City.	A Jan. 16, 1895 M Apr. 26, 1901
BURCH, EDWARD P., Consulting Electrical Engineer, Minneapolis, Minn.	A Jan. 28, 1898 M May 17, 1898

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Burgess, Chas. Fredk., Asst. Prof. of Electrical Engineering, University of Wisconsin, Madison Wis.	A Mar. 25, 1896 M Apr. 26, 1901
Burke, James, Electrical Engineer, Burke Electric, Erie, Pa.	A May 16, 1893 M July 28, 1903
Burleigh, Chas. B., Electrical Engineer, General Electric Co., 84 State St., Boston, Mass.	A Apr. 21, 1891 M Feb. 16, 1892
Burnett, Douglass, *B. S.*, Manager Elec. Dept., Cons. G. E. L. & P. Co., Baltimore, Md.	A Feb. 21, 1893 M Nov. 25, 1904
Burt, Byron T., General Manager, Chattanooga Electric Co., Chattanooga, Tenn.	A Sep. 25, 1895 M Feb. 28, 1902
Burton, William C., Electrical Engineer, J. G. White & Co., 22a College Hill, London, E. C., Eng.	A Sep. 20, 1893 M Dec. 27, 1899
Caldwell, Francis Cary, Professor Elec. Engineering, Ohio State Univ., Columbus, O.	A June 20, 1894 M Jan. 24, 1902
Carhart, Henry S., *A.M.* and *LL.D.*, Prof. of Physics, University of Michigan, Ann Arbor, Mich.	A Sep. 25, 1895 M Apr. 22, 1896
Carichoff, E. R., General Consulting Engineer, 20 Broad St., New York City.	A Mar. 21, 1894 M May 15, 1900
Carty, John J., [*Manager*] Chief Engineer, Am. Tel. & Tel. Co., 15 Dey St., N. Y. City.	A Apr. 15, 1890 M Nov. 20, 1903
Carus-Wilson, Charles A., Consulting Engineer, 41 Old Queen St., Westminster, London, Eng.	A Apr. 18, 1894 M Apr. 17, 1895
Chandler, Charles F., Professor of Chemistry, Columbia University, New York City.	A Jan. 20, 1891 M June 7, 1892
Cheney, W. C., Electrical Engineer, Kalama Electric Light & Power Co., Kalama, Wash.	A Sep. 22, 1891 M Nov. 21, 1894
Chesney, Cummings C. [*Manager*], 1st V.-P. and Chief Eng'r, Stanley G.I. Elec Mfg. Co., Pittsfield, Mass.	A June 20, 1894 M Nov. 22, 1899
Cheyney, Algernon Roberts, Station Supt., Phila. Electric Co., Philadelphia, Pa.	A Apr. 23, 1903 M July 26, 1907
Chubbuck, H. Eugene, Manager, Quincy Horse Railway and Carrying Co., La Salle, Ill.	A Dec. 4, 1888 M Apr. 26, 1899
Clark, Eugene Bradley, Electrical Engineer, Illinois Steel Co.; res., 5335 Cornell Ave., Chicago, Ill.	A Mar. 28, 1902 M Nov. 20, 1903
Clark, LeRoy, V.-P. and Treasurer, Safety Insulated Wire and Cable Co., 114 Liberty St., New York.	A May 15, 1894 M June 19, 1903
Clarke, Chas. L., *M.S.*, *C.E.*, Electrical and Mechanical Engineer, 120 Broadway, New York City.	A Apr. 15, 1884 M Jan. 6, 1885
Clausen, Henry P., Manager and Designer, American Electric Telephone Co., Chicago, Ill.	A May 19, 1903 M July 28, 1903
Clifford, Harry Ellsworth, Prof. Theoretical Electricity, Mass. Inst. of Technology, Boston, Mass.	A May 15, 1905 M Mar. 1, 1907
Colby, Edward A., Consulting Engineer, Lock Box 113, Newark, N. J.	A Apr. 2, 1889 M May 7, 1889
Cole, Wm. Howard, Consulting Engineer, 564 Cangallo, Buenos Aires, Argentine Rep.	A Apr. 25, 1900 M Oct. 23, 1903
Cole, William Weeden, President and Gen. Manager, Elmira Water, Light and R.R. Co., Elmira, N.Y.	A April 25, 1902 M Oct. 23, 1903
Comstock, Louis K., Electrical Engineer, 114 Liberty St., New York City.	A Dec. 20, 1893 M Nov. 20, 1895
Condict, G. Herbert, Electrical Engineer, 115 Broadway, New York City.	A July 12, 1887 M Sep. 6, 1887
Cook, Edward Jerome, General Manager, Rochester Railway Co., 267 State St., Rochester, N.Y.	A May 15, 1900 M Nov. 25, 1904

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COOPER, ARTHUR THOMAS, Chf. Engineer, Bombay Electric Supply & Tramways Co. Ltd. Bombay, India.	A Jan. 26, 1906 M Oct. 26, 1906
COOPER, WILLIAM, Consulting Electrical and Mechanical Engineer, 548 Oakwood St., Wilkinsburg, Pa.	A Feb. 28, 1902 M July 25, 1902
COREY, FRED BRAINARD, Engineer, General Electric Co.; res., 1009 Nott St., Schenectady, N. Y.	A Dec. 20, 1893 M Feb. 26, 1904
CORNELL, CHARLES L., Treasurer, Niles-Bement-Pond Co., 111 Broadway, New York City.	A Feb. 7, 1890 M June 27, 1895
CORY, CLARENCE L., Professor of Electrical Engineering, University of California, Berkeley, Cal.	A Apr. 19, 1892 M July 28, 1903
COSTER, MAURICE, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City.	A Sep. 25, 1895 M Mar. 25, 1896
COWLES, ALFRED H., President the Cowles Electric Smelting and Aluminum Co., Cleveland, O.	A Mar. 5, 1886 M May 7, 1889
COWLES, JOSEPH W., Electrical Engineer, Edison, Electric Illuminating Co., 3 Head Pl., Boston, Mass.	A Aug. 22, 1902 M July 28, 1903
COX, FRANK POWELL, Electrical Engineer, General Electric Co., Lynn, Mass.	A Oct. 25, 1901 M Apr. 25, 1902
CROCKER, FRANCIS BACON, *E.M., Ph.D.* [*Past-President*] [Life Member.] Prof. E.E., Columbia Univ., New York.	A May 24, 1887 M Apr. 2, 1889
CROSS, CHARLES R., Thayer Professor Physics, Mass. Institute of Technology, Boston, Mass.	A Apr. 15, 1884 M Oct. 21, 1884
CUSHING, HARRY COOKE, JR., Consulting Electrical Engineer, 220 Broadway, New York City.	A Sep. 19, 1894 M Nov. 18, 1896
CUTTER, GEORGE, President, George Cutter Co., South Bend, Ind.	A June 17, 1890 M Nov. 18, 1896
DAFT, LEO, Consulting Electrical Engineer, 135 Sylvan St., Rutherford, N. J.	A Dec. 9, 1884 M Jan. 6, 1885
DARLINGTON, FREDERICK, Consulting Electrical Engineer, Great Barrington, Mass. [Life Member.]	A Nov. 21, 1902 M Apr. 24, 1903
DAVIDSON, A., Cable Engineer and Electrician, Central and South American Telegraph Co., Lima, Peru.	A May 18, 1897 M Oct. 27, 1897
DAVIS, ALBERT GOULD, Manager, Patent Dept., General Electric Co., Schenectady, N. Y.	A Mar. 23, 1898 M Sep. 26, 1900
DAVIS, CHARLES H., *C.E.*, Consulting Engineer, Broad-Exchange Bldg., New York City.	A Mar. 18, 1890 M June 17, 1890
DAVIS, HARRY PHILLIPS, Engineer of Detail Dept., Westinghouse E. & M. Co., Pittsburg, Pa.	A Jan. 25, 1901 M Sep. 27, 1901
DAVIS, JOSEPH P., Engineer, American Telephone and Telegraph Co., 1170 Broadway, New York City.	A Apr. 15, 1884 M Mar. 25, 1904
DAVIS MINOR M., Assistant Electrical Engineer, Postal Tel.-Cable Co., 253 Broadway, New York City.	A Apr. 6, 1886 M May 16, 1893
DEAN, ERNEST WILLIAM, Buenos Ayres & Rosario Ry. Co., Ltd., Rosario de Santa Fe, A. R.	A June 15, 1904 M Aug. 25, 1905
DECKER, EDWARD P., Engineer, with Westinghouse, Church, Kerr & Co., 10 Bridge St., New York.	A Feb. 26, 1896 M Oct. 27, 1897
DE FERRANTI, SEBASTIEN ZIANA, Managing Director, de Ferranti, Ltd., London, Eng.	A May 19, 1903 M Oct. 26, 1906
DE FODOR, ETIENNE, General Manager, Budapest General Electric Co., Budapest, Hungary.	A Mar. 25, 1904 M Jan. 27, 1905
DE FOREST, LEE, Scientific Director, De Forest Wireless Telegraph Co., New York City.	A Mar. 25, 1904 M Mar. 1, 1907

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DELANY, PATRICK BERNARD, Inventor, South Orange, N. J.	A Apr. 19, 1884 M Nov. 24, 1891
DENHAM, JOHN, Electrician, Cape Government, Cape Town, South Africa.	A Jan. 24, 1900 M May 15, 1900
DE WAAL, WM. H., Engineer, Mexico City, Mexico.	A Apr. 25, 1900 M June 19, 1903
DICK, WILLIAM AMZI, Designing Electrical Engineer, Westinghouse E. & M. Co., Pittsburg, Pa.	A Mar. 28, 1902 M Nov. 25, 1904
DICKENSON, SAMUEL S., Superintendent, Commercial Cable Co., 253 Broadway, N. Y. City.	A Mar. 6, 1888 M Oct. 1, 1889
DIEHL, PHILIP, Inventor, Singer Sewing Machine Co.: res., 528 Morris Ave., Elizabeth, N. J.	A Apr. 15, 1884 M Dec. 9, 1884
DION, ADOLPHE ALFRED, General Supt., The Ottawa Electric Co., 35 Sparks St., Ottawa, Ont.	A Jan. 7, 1890 M Nov 15, 1893
DOANE, SAMUEL EVERETT, Chief Engineer National [Life Member.] Electric Lamp Association, Cleveland, O.	A Aug. 6, 1889 M June 27, 1895
DODD, SAMUEL THOMSON, Railway Engineering Dept., General Electric Co., Schenectady, N. Y.	A Sept. 27, 1901 M Dec. 15, 1905
DODGE, OMENZO G., Prof. U. S. Navy, Naval Academy, Annapolis, Md.	A Sep. 20, 1893 M Apr. 17, 1895
DOHERTY, HENRY L., 60 Wall St., New York City.	A Sep. 28, 1898 M July 25, 1902
DOMMERQUE, FRANZ J., Kellogg Switchboard and Supply, cor. Congress and Green Sts., Chicago, Ill.	A Oct. 17, 1894 M Mar. 25, 1896
DONNER, WILLIAM H., Grindleford Bridge, Sheffield, Eng.	A Nov. 18, 1890 M Dec. 16, 1890
DOW, ALEX, Manager, Edison Illuminating Co., 18 Washington Ave.; res., 844 Cass Ave., Detroit.	A Sep. 20, 1893 M Dec. 18, 1895
DOYER, H., Electrical Engineer, 112 Cloes de Vriese laan Rotterdam, Holland.	A Jan. 7, 1890 M Mar. 18, 1890
DUDLEY, CHARLES B., Chemist, Penn. R. R. Co., Drawer 334, Altoona, Pa.	A Oct. 1, 1889 M Nov. 12, 1889
DUNBAR, F. W., Engineer, 5210 Jefferson Ave., Chicago, Ill.	A Dec. 21, 1892 M May 16, 1893
DUNCAN, DR. LOUIS, [*Past-President*] Consulting Engineer, 56 Pine St., New York City.	A July 12, 1887 M Sep. 6, 1887
DUNLAP, WILL KNOX, Electrical Engineer, Westinghouse Elec. & Mfg. Co., Pittsburg, Pa.	A Sep. 25, 1889 M June 24, 1895
DUNN, GANO, *M. S., E. E.*, Vice-Pres. & Chief Eng'r, [Life Member.] C.-W. Co., Ampere, N. J.	A Apr. 21, 1891 M June 20, 1894
DUSINBERRE, GEORGE BROWN, Consulting Engineer, 517 Electric Building, Cleveland, O.	A Nov. 22, 1901 M July 25, 1902
DYER, R. N., Patent Attorney, 31 Nassau St., New York City.	A July 12, 1887 M Sep. 6, 1887
EASTERBROOK, JOHN F., Consulting Engineer, 82 York Sq., New Haven, Conn.	A Nov. 21, 1902 M June 19, 1903
EASTWOOD, ARTHUR CLARKE, Engineer, Electric Controller and Supply Co., Cleveland, Ohio.	A Mar. 27, 1903 M Nov. 25, 1904
EDGAR, C. L. [*Manager*], President Edison Elec. Illuminating Co. of Bost., 70 State St., Boston, Mass.	A Jan. 22, 1896 M May 19, 1896
EDISON, THOMAS A., Mechanician and Inventor, Llewellyn Park, N. J.	A Apr. 15, 1884 M Oct. 21, 1884
EDMONSTON, EDGAR DAVIS, Electrical Engineer, W. S. Barstow & Co., 50 Pine St., New York City.	A Apr. 25, 1902 M Mar. 1, 1907

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Egger, Ernst, Tech. Director, Vereinigte Elektricitäts-Actien Gesellschaft, Vienna, X., Austria.	A Feb. 21, 1893 M Mar. 21, 1894
Eglin, Wm. C. L. [*Vice-President*], Electrical Engineer, Philadelphia Electric Co., Philadelphia, Pa.	A Sep. 19, 1894 M Mar. 1, 1907
Emmet, W. L. R., Electrical Engineer, General Electric Co., Schenectady, N. Y.	A June 6, 1893 M Jan. 17, 1894
Ensign, Orville Hiram, Consulting Engineer, U. S. Reclamation Service, Los Angeles, Cal.	A Dec. 23, 1904 M Dec. 15, 1905
Esty, William, Prof. Electrical Engineering, Lehigh Univ., So. Bethlehem, Pa.	A Mar. 20, 1895 M Apr. 24, 1903
Everest, Augustine Robert, Electrical Engineer, British Thomson Houston Co., Rugby, Eng.	A Jan. 29, 1904 M Apr. 22, 1904
Ferguson, Louis Aloysius, [*Vice-President*] 2d V. P., Chicago Edison Co., 139 Adams St., Chicago, Ill.	A Oct. 25, 1901 M Aug. 17, 1904
Fessenden, Reginald A., National Electric Signalling Co., 8th and Water St., S. W., Washington, D. C.	A Oct. 21, 1890 M Dec. 16, 1890
Field, Henry George, Director and Secretary, Buick Motor Co., Flint, Mich.	A Apr. 22, 1896 M Dec. 16, 1896
Field, Michael Birt, Contract Engineer, 8 St. Paul's Road, Kersal, Manchester, Eng.	A Nov. 20, 1903 M Dec. 15, 1905
Field, Stephen D., Electrical Engineer, Stockbridge, Mass.	A Apr. 15, 1884 M Oct. 21, 1884
Fish, Walter Clark, Manager Lynn Works, General Electric Co., Lynn, Mass.	A June 26, 1891 M Feb. 26, 1896
Fisher, Henry W., Supt,. Pittsburg Factory,& E.Engr, Standard Underground Cable Co., Pittsburg.	A Jan. 16, 1895 M Apr. 26, 1901
Fitch, Derick H., Manager, Cazenovia Telephone Co., Cazenovia, N. Y.	A Sep. 28, 1906 M Dec. 28, 1906
Fitzmaurice, James S., [*Local Hon. Secretary*], Assist. Elec. Engineer, Post. Gen. Dept., Sydney, N.S.W.	A Sep. 20, 1893 M Mar. 21, 1894
Flack, J. Day, *M.E.*, Engineer and Salesman, C. W. Hunt Co., West Brighton, N. Y.	A Dec. 6, 1887 M May 21, 1895
Ford, Arthur Hillyer, *E.E.*, Prof. of Electrical Engineering, Univ. of Iowa, Iowa City, Iowa. [Life Member]	A Mar. 24, 1897 M Jan. 24, 1904
Fortenbaugh, S. B., Electrical Engineer, General Electric Co., Schenectady, N. Y.	A Apr. 17, 1895 M Dec. 16, 1896
Foster Horatio A., Resident Engineer, 1314 Continental Trust Building, Baltimore, Md.	A June 8, 1887 M Sep. 6, 1887
Foster, Samuel L., Chief Electrician, United Railroads of S. F.; res. 3687 24th St., San Francisco.	A Feb. 26, 1896 M Nov. 18, 1896
Franklin, W. S., Professor of Physics, Lehigh University, Bethlehem, Pa.	A Jan. 22, 1896 M Sep. 26, 1902
Freedman, William H., Professor of Electrical Engineering, University of Vermont, Burlington, Vt.	A Mar. 18, 1890 M Dec. 18, 1895
Gale, Horace B., Chief Engineer, Simplex Electric Heating Co., Cambridge, Mass.	A Nov. 15, 1892 M May 16, 1893
Ganz, Albert F., Professor of Electrical Engineering, Stevens Institute of Technology, Hoboken, N. J.	A Apr. 26, 1899 M June 19, 1902
Garfield, Alex. Stanley, Engineer, 67 Avenue de Malakoff, Paris, France.	A Jan. 26, 1898 M June 28, 1901
Garratt, Allan V., Chief Engineer, Lombard Governor Co., Ashland; res., Holliston, Mass.	A Apr. 2, 1889 M May 7, 1889

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GERRY, M. H., JR., Chief Engineer and General Manager, Missouri River Power Co., Helena, Mont.	A Apr. 18, 1893 M Oct. 21, 1896
GHERARDI, BANCROFT, *B.S.*, *M.M.E.* [*Manager*], Eng., Am. Tel. & Tel. Co., 15 Dey St., New York City.	A June 27, 1895 M July 19, 1904
GHERKY, WILLIAM D., Engineer & Contractor, Heed Bldg., 1211 Filbert St., Philadelphia, Pa.	A May 21, 1895 M Feb. 26, 1896
GIBBS, GEORGE, Chief Eng'r Electric Traction, P. N. Y. & L. I. R.R. Co., 10 Bridge St., New York City.	A Apr. 28, 1905 M Dec. 15, 1905
GIBBS, HARRY PARKER, Chief Electrical Engineer Cauvery Power Scheme, Bangalore, India.	A Sept. 26, 1902 M Nov. 25, 1904
GIFFORD, CLARENCE E., *E. E.*, Buffalo Office, General Electric Co.; res., 907 Prospect Av., Buffalo, N.Y.	A May 16, 1893 M Feb. 21, 1894
GILLETTE, JAMES WALTER, Manager Ft. Smith Lt. and Traction Co., Ft. Smith, Arkansas.	A Feb. 27, 1903 M Sept. 22, 1905
GILMAN, FRANCIS LYMAN, Telephone Engineer, Western Electric Co., 463 West St., New York City.	A June 28, 1901 M May 21, 1907
GLADSON, WM. N., Professor of Electrical Engineering. University of Arkansas, Fayetteville, Ark.	A Dec. 28, 1898 M Jan. 24, 1902
GODDARD, CHRIS. M., *B.S.*, Secy. Underwriters' National Electric Assn., 55 Kilby St., Boston, Mass.	A Apr. 22, 1896 M Feb. 28, 1902
GOLDSBOROUGH, WINDER ELWELL, *M.E.* [*Vice-Pres.*], 1st V.-P., Denver Reservoir Irrig. Co., Denver, Col.	A Mar. 21, 1893 M Jan. 25, 1899
GOLTZ, WILLIAM, Consulting Electrical Engineer, Goltz Engineering Co., 319 S. Clinton St., Chicago, Ill.	A Oct. 27, 1897 M Feb. 23, 1898
GONZENBACH, ERNEST, General Manager, Sheboygan Lt., Power & Railway Co., Sheboygan, Wis.	A Jan. 23, 1903 M Aug. 17, 1904
GOODMAN, WM. GEO. TOPP, [*Local Honorary Secretary.*] Electrical Engineer, Noyes Bros., Dunedin, N.Z.	A Aug. 23, 1899 M May 15, 1900
GOSSLER, PHILIP GREEN, 2d Vice-President, J. G. White & Co., 43 Exchange Pl., New York City.	A June 20, 1894 M June 24, 1898
GOTSHALL, WM. C., Consulting Engineer, 76 William St., New York City.	A Jan. 9, 1901 M Jan. 24, 1902
GREENIDGE, CHARLES AUSTIN, General Manager Electric Dept., Utica Gas & Electric Co., Utica, N. Y.	A June 19, 1903 M April 27, 1906
GREENWOOD, WALTER GEORGE, Electrical Engineer, General Electric Co., Mexico City, Mexico.	A Jan. 24, 1900 M Oct. 24, 1902
GREGG, TOM HOWARD, Supt. Electrical Construction, U. S. Light House Board, Tompkinsville, N. Y.	A. Mar 22, 1899 M Sep. 26, 1900
GROWER, GEORGE G., Electrician and Chemist, Ansonia Brass and Copper Co., Ansonia, Conn.	A Mar. 18, 1890 M Oct. 27, 1905
GUTMANN, LUDWIG, Electrical Engineer, 5645 Cates Ave., St. Louis, Mo.	A Sep. 14, 1888 M Mar. 21, 1893
HADAWAY, W. S. JR., Electric Heating Engineer, 228 West Broadway, New York City.	A Nov. 21, 1894 M Oct. 21, 1896
HADLEY, ARTHUR L., Electrical Engineer, Fort Wayne Electric Works, Fort Wayne, Ind.	A Oct. 17, 1894 M Mar. 22, 1901
HADLEY, FREDK. W., Electrical Engineer, 1327 Empire [Life Member.] Bldg., Atlanta, Ga.	A Aug. 5, 1896 M Feb. 28, 1901
HAFER, GEORGE, JR., Lenox Hotel, Buffalo, N. Y.	A Nov. 23, 1900 M Apr. 26, 1901
HALL, JOHN L., District Mgr., Holtzer-Cabot Elec. Co., 1329 Real Estate & Trust Bldg., Philadelphia, Pa.	A Sep. 22, 1891 M Dec. 20, 1893

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HALL, WALTER ATWOOD, Assistant Engineer, General Electric Co., Pittsfield, Mass.	A Apr. 23, 1903 M Oct. 23, 1903
HAMILTON, GEO. A. [*Treasurer*], Electrician, Western Electric Co., 463 West St., New York City.	A Apr. 15, 1884 M Oct. 21, 1884
HAMMER, EDWIN W., Electrical Engineer, 120 Broadway, New York City.	A Nov. 18, 1896 M June 23, 1897
HAMMER, WILLIAM J., Consulting and Supervising Electrical Eng'r, 26 Cortlandt St., New York. [Life Member.]	A June 8, 1887 M July 12, 1887
HAMMOND, ROBERT. Consulting Electrical Engineer, 64 Victoria St., Westminster, London, S.W., Eng.	A Nov. 25, 1904 M Oct. 26, 1906
HANCHETT, GEO. T., Electrical and Mechanical Engineer, 114 Liberty St., New York City.	A May 19, 1896 M Feb. 15, 1899
HARPER, JOHN LYELL, Chief Engineer, Niagara Falls Hydraulic Power & Mfg. Co., Niagara Falls, N.Y.	A Apr. 26, 1907 M July 26, 1907
HARRINGTON, WALTER E., Operating Manager, J. G. White, 43 Exchange Pl., New York City.	A Mar. 17, 1891 M May 19, 1899
HARTMAN, HERBERT T., 2d V. P. and Chief Engineer, 1532 Land Title Bldg., Philadelphia, Pa.	A Mar. 21, 1893 M May 19, 1903
HARTWELL, ARTHUR, Secretary and Treasurer Detroit Insulated Wire Co., Detroit, Mich.	A May 15, 1894 M Nov. 20, 1895
HASKINS, CARYL DAVIS, Electrical Engineer, General Electric Co., Schenectady, N. Y.	A Mar. 18, 1890 M June 20, 1894
HAYES, HAMMOND V., Electrical Engineer, American Telephone & Tel. Co., 125 Milk St., Boston, Mass.	A Nov. 12, 1889 M Mar. 18, 1890
HAYES, HARRY E., Asst. Electrician, American Telegraph and Telephone Co., 125 Milk St., Boston.	A Apr. 18, 1893 M Dec. 20, 1893
HAYES, STEPHEN Q., Switchboard Engineer, Westinghouse E. & M. Co., Pittsburg, Pa.	A Sept. 25, 1903 M July 28, 1905
HAYWARD, ROBERT FRANCIS, Mexico Light and Power Co., Ltd., Mexico, D. F.	A Apr. 23, 1903 M Apr. 26, 1907
HEATH, HARRY E., Engineer, General Electric Co., Lynn, Mass.	A Mar. 21, 1893 M Mar. 25, 1896
HEINRICH, RICHARD O., European Weston Electrical Instrument Co., 88 Ritterstrasse, Berlin, Ger.	A Oct. 1, 1889 M Oct. 25, 1892
HEITMANN, EDWARD, JR., Electrical Engineer, Crocker-Wheeler Co., Ampere, N. J.	A Oct. 24, 1900 M June 19, 1903
HENSHAW, FREDERICK V., Elec. and Mech. Eng'r, 90 Wall St., New York; res., 79 State St., Brooklyn.	A Feb. 5, 1889 M Nov. 20, 1895
HERDMAN, FRANK E., Mechanical and Electrical Engineer, Otis Elevator Co., Chicago, Ill.	A Dec. 18, 1895 M Oct. 21, 1896
HERDT, LOUIS A., Lecturer on Electrical Engineering, McGill University, Montreal, Canada.	A May 16, 1899 M Feb. 23, 1906
HERING, CARL, [*Past-President*] Consulting Electrical Eng'r, 929 Chestnut St., Philadelphia. [Life Member.]	A Jan. 3, 1888 M June 5, 1888
HERRICK, ALBERT B., Consulting Electrical Engineer, Ridgewood, N. J.	A May 21, 1901 M Apr. 26, 1907
HERRICK, CHARLES H., Contract Agent, Edison Electric Illuminating Co. 3 Head Pl., Boston, Mass.	A Apr. 21, 1891 M Jan. 17, 1893
HERZOG, F. BENEDICT, *Ph. D.*, President, Herzog Telesme Co., 51 W. 24th St., New York City.	A May 24, 1887 M July 12, 1887
HESKETH, THOMAS, Managing Engineeer, Folkestone Electricity Supply Co., Ltd., Folkestone, Eng.	A Nov. 25, 1904 M Oct. 26, 1906
HEWITT, CHARLES, Electrical Engineer, Philadelphia Rapid Transit Co., Philadelphia, Pa.	A Sep. 16, 1890 M May 17, 1892

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HEWITT, PETER COOPER, 11 Lexington Ave., New York City. — A May 21, 1901; M Mar. 1, 1907

HEWLETT, ERNEST HOLCOMBE, Borough Electrical Engineer, Lime Tree Place, Mansfield, Eng. — A Aug. 23, 1899; M Dec. 27, 1899

HIBBARD, ANGUS S., General Manager, Chicago Telephone Co., 203 Washington St., Chicago, Ill. — A Nov. 24, 1891; M Feb. 16, 1892

HIGGINS, EDWARD E., Treasurer Success Magazine 32 Waverly Pl., New York City. — A June 8, 1887; M July 12, 1887

HILL, ERNEST ROWLAND, Electrical Engineer, with George Gibbs, 10 Bridge St., New York City. — A Jan. 25, 1899; M Jan. 27, 1905

HILL, GEORGE, *C.E.*, Consulting Engineer, 12 W. 40th St., New York City. — A April 19, 1892; M June 28, 1901

HOBART, HENRY M., Consulting Engineer, Oswaldestre House, Norfolk St., Strand, London, Eng. — A Apr. 18, 1894; M Sep. 27, 1899

HOLMES, FRANKLIN S., Electrical Engineer, 26 Cortlandt St., New York City. — A Apr. 21, 1891; M June 20, 1894

HOOPES, MAURICE, Mechanical Engineer, J. G. White & Co., Glens Falls, N. Y. — A Nov. 22, 1901; M July 25, 1902

HOSMER, SIDNEY, Supt., Installation Bureau, Edison Electric Illuminating Co., 3 Head Pl., Boston. — A May 18, 1897; M Jan. 24, 1902

HOUSTON, EDWIN J., *Ph.D.* [*Past-President*] Electrical Expert, Patent Causes, Philadelphia, Pa. [Life Member.] — A Apr. 15, 1884; M Oct. 21, 1884

HOWELL, JOHN W., Engineer, Lamp Works, General Electric Co., Harrison, N. J. — A July 12, 1887; M June 5, 1888

HOWELL, WILSON S., Manager, Electrical Testing Laboratories, 556 E. 80th St., New York City. — A Sep. 3, 1889; M Mar. 18, 1890

HOWLAND, LEWIS A., Nassau Light & Power Co., Roslyn, N. Y. — A July 26, 1900; M Feb. 28, 1902

HUBLEY, GEORGE WILBUR, Supt. and Electrical Engineer, Louisville Lighting Co., Louisville, Ky. — A Sep. 19, 1894; M May 15, 1900

HULSE, WM. S., Consulting Engineer, Roteng Engineering Corporation, 299 Broadway, New York City. — A Mar. 25, 1896; M Aug. 25, 1905

HUMPHREY, HENRY H. [*Vice-President*], Consulting Elec. Engr., Suite 1505 Chemical Bldg., St. Louis, Mo. — A Dec. 16, 1896; M April 28, 1897

HUNT, ANDREW MURRAY, Electrical Engineer, 202 California St., San Francisco, Cal. — A Feb. 28, 1900; M July 28, 1903

HUNTER, RUDOLPH M., Expert and Counsellor in Patent Causes, 926 Walnut St., Philadelphia, Pa. — A July 13, 1886; M May 17, 1887

HUNTING, FRED S., Sales Manager and Treasurer, Fort Wayne Electric Works, Fort Wayne, Ind. — A Nov. 15, 1892; M May 16, 1893

HUNTINGTON, DAVID L., 2d Vice-President & General Mgr. Washington W. P. Co., Spokane, Wash. — A May 20, 1902; M Sep. 26, 1902

HUTCHINSON, CARY TALCOTT, Consulting Electrical Engineer, 60 Wall St., New York City. [Life Member.] — A Feb. 7, 1890; M Dec. 16, 1890

HUTTON, CHARLES WILLIAM, Designing Electrical Engineer, Sacramento, Cal. — A Feb. 15, 1899; M July 28, 1903

IHLDER, JOHN D., Electrical Engineer, Otis Elevator Co., 17 Battery Place, New York City. — A Oct. 2, 1888; M June 19, 1903

IMLAY, LORIN EVERETT, Assistant Superintendent, Niagara Falls Power Co., Niagara Falls, N. Y. — A July 26, 1900; M Nov. 20, 1903

JACKSON, DUGALD C., Consulting Engineer, D. C. & Wm. B. Jackson, Madison, Wis. — A May 3, 1887; M June 17, 1890

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JACKSON, JOHN PRICE, Professor of Electrical Engineering, Penn. State College, State College, Pa.	A Sep. 27, 1892 M Jan. 17, 1894
JACKSON, WM. B., Consulting Engineer, Dugald C. & Wm. B. Jackson, Madison, Wis. [Life Member.]	A Aug. 13, 1897 M June 24, 1898
JEHL, FRANCIS, I Meszaros utcza 30, Budapest, Austria-Hungary.	A June 27, 1895 M Jan. 22, 1896
JENKS, WILLIAM J., Secretary, Board of Patent Control, 120 Broadway, New York City	A June 8, 1887 M Nov. 1, 1887
JEWETT, ALBERT CAVALLO, Electrical Engineer, Mohora Jhelum, Valley Road, Kashmir, India. [Life Member.]	A Apr. 27, 1906 M Mar. 1, 1907
JOHANNESEN, SVEND EMANUEL, Electrical Engineer, General Electric Co., Schnectady, N. Y.	A Jan. 23, 1903 M Apr. 24, 1903
JONES, BENJAMIN NEEDHAM, Asst. Gen. Supt., Otis Elevator Co., 17 Battery Place, New York City.	A Oct. 24, 1902 M June 19, 1903
JONES FRANCIS WILEY, Electrical Engineer, 86 Wadsworth Ave., New York City. [Life Member.]	A Apr. 15, 1884 M Oct. 21, 1884
JONES, FRED ATWOOD, Consulting Electrical, Mechanical and Hydraulic Engineer, Houston, Tex.	A Jan. 24, 1902 M Feb. 24, 1905
JONES, ROBERT CLAY, Turnbull & Jones, Electrical Engineers and Contractors, Dunedin, N. Z.	A Oct. 24, 1902 M Oct. 27, 1905
JUNKERSFELD, PETER, Asst. to Mechanical Engineer, Chicago Edison Co., Chicago, Ill.	A Oct. 25, 1901 M Apr. 26, 1907
KATTE, EDWIN BRITTON, Electrical Engineer, N. Y. C. & H. R. R. R. Co.; G. C. Station, New York City.	A Feb. 27, 1903 M July 19, 1904
KEITH, NATHANIEL S., Mining and Metallurgical Engineer, 350 Bullitt Building, Philadelphia, Pa.	A Apr. 15, 1884 M Jan. 17, 1894
KELLY, JOHN F., *Ph.D.*, President Telelectric Co., Pittsfield. Mass.	A May 16, 1899 M July 25, 1902
KELSCH, RAYMOND STERLING, Gen. Supt. and Engineer, The L. R. H. & L. Co., 160 McCord St., Montreal.	A May 20, 1902 M May 19, 1903
KENAN, WM. R., JR., 242 Genesee St., Lockport, N. Y.	A Jan. 20, 1897 M Apr. 26, 1901
KENNEDY, JEREMIAH J., Consulting Engineer, 52 Broadway, New York City.	A July 26, 1900 M July 25, 1902
KENNELLY, ARTHUR E., *D.Sc.*, [*Past-President*] Dept. of Eng., Harvard Univ., Cambridge, Mass. [Life Member.]	A May 1, 1888 M May 16, 1899
KENYON, ALFRED LEWIS, Chief Engineer, Empresa Electrica de Santa Rosa, Lima, Peru, S. A.	A Sept. 25, 1903 M Feb. 24, 1905
KILGOUR, HAMILTON, Canadian Bank of Commerce, 16 Exchange Pl., New York City.	A Apr. 26, 1901 M Jan. 24, 1902
KINSMAN, FRANK E., Electrical Engineer, 55 Dey St., New York City; res., Plainfield, N. J.	A Sep. 27, 1892 M May 16, 1893
KINTNER, SAMUEL MONTGOMERY, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg.	A Feb. 28, 1902 M July 28, 1903
KIRKER, HARRY LEPPER, Westinghouse E. & M. Co., Pittsburgh, Pa.	A Feb. 27, 1903 M Oct. 26, 1906
KIRKLAND, JOHN W., Vice President McCall Ferry Power Co., 60 Wall St., New York City.	A Mar. 21, 1894 M Sep. 26, 1900
KLINCK, J. HENRY, Commercial Engineer, Industrial & Power Dept., W. E. & Mfg. Co., Pittsburg, Pa.	A Jan. 16, 1895 M July 26, 1907
KNOWLES, EDWARD R., *E.E.*, *C.E.*, Consulting Electrical Engineer, 120 Liberty St., New York City.	A June 8, 1887 M July 12, 1887

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KNOX, CHAS. EDWIN, With C. O. Mailloux, Consulting Electrical Engineer, 76 William St., New York.	A May 16, 1899 M Dec. 27, 1899
KNUDSON, A. A., Electrical Engineer, Room 416, 32 Nassau St., New York City.	A Dec. 6, 1887 M Jan. 3, 1888
KOINER, C. WELLINGTON, General Superintendent, Los Angeles Gas & Electric Co., Los Angeles, Cal.	A Oct. 28, 1904 M Apr. 26, 1907
LAMME, BENJAMIN G. [*Manager*], Assist. Chief Engineer, Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.	A May 19, 1903 M July 28, 1903
LANGE, PHILIP A., Br. Westinghouse Electric and Mfg. Co., Trafford Pk., Manchester, Eng.	A Mar. 6, 1888 M June 5, 1888
LANGSDORF, ALEXANDER SUSS, Prof. Elec. Engineering, Washington University, St. Louis, Mo.	A Jan. 23, 1903 M Mar. 29, 1907
LANGTON, JOHN, Engineer, 99 John St., New York [Life Member.] City.	A Mar. 6, 1888 M June 5, 1888
LARDNER, HENRY ACKLEY, Chief Electrical Engineer, J. G. White & Co., 43 Exchange Pl., New York.	A Dec. 19, 1894 M May 16, 1899
LAYMAN, W. A., Manager and Treasurer, Wagner Electric Mfg. Co., 2017 Locust St., St. Louis, Mo.	A Nov. 22, 1899 M Nov. 23, 1900
LEE, FRANCIS VALENTINE T., Engineer, cor. 59th St. and College Ave., Oakland, Cal.	A Mar. 23, 1898 M Dec. 19, 1902
LEE, WILLIAM S., JR., Chief Engineer, Southern Power Co., Charlotte, N. C.	A May 17, 1904 M July 26, 1907
LEMP, HERMANN, JR., Electrician, General Electric Co.; res., 186 Allen Ave., Lynn, Mass.	A Apr. 2, 1889 M Feb. 21, 1893
LEONARD, H. WARD, Electrical Engineer, Prest. Ward [Life Member.] Leonard Electric Co., Bronxville, N. Y.	A July 12, 1887 M Sep. 6, 1887
LEWIS, WARREN B., Consulting Engineer, Room 732 Banigan Bldg., Providence, R. I.	A Jan. 23, 1903 M June 19, 1903
LEYDEN, HARRY RUSSELL, 30 Broad St., New York City	A Nov. 23, 1900 M Feb. 28, 1901
LIEB, JOHN WILLIAM, JR. [*Past-President*], Assoc. Gen. Mgr., N. Y. Edison Co., 53 Duane St., New York.	A Sep. 6, 1887 M Nov. 1, 1887
LIGHTHIPE, JAMES A., Engineer, General Electric Co., Union Savings Bk. Bldg., Oakland, Cal.	A Feb. 21, 1894 M Apr. 17, 1895
LINCOLN, PAUL M. [*Manager*], Westinghouse Electric and Mfg. Co., Pittsburg, Pa.	A Sep. 25, 1895 M June 24, 1898
LLOYD, HERBERT, Vice-President, Electric Storage Battery Co., Allegheny Ave. & 19th St., Philadelphia.	A June 20, 1894 M May 21, 1895
LOCKWOOD, THOMAS D., Manager Patent Dept., Am. [Life Member.] Teleph. & Tel. Co., 119 Milk St., Boston.	A Apr. 15, 1884 M Oct. 21, 1884
LOOMIS, OSBORN P., Electrical Engineer, Newport News Shipbuilding and D. D. Co., Newport News, Va.	A Sep. 16, 1890 M Dec. 16, 1896
LORPAIN, JAMES GRIEVE, *M.I.E.E.*, *M.I.Mech.E.*, Chartered Patent Agent, Norfolk House, London, Eng.	A May 16, 1891 M May 15, 1894
LOVEJOY, J. R., Manager, Railway Lighting & Supply Dept., General Electric Co., Schenectady, N. Y.	A Apr. 21, 1891 M Feb. 21, 1894
LOZIER, ROBERT T. E., Dodge & Day, 115 Broadway, New York City.	A May 20, 1890 M Jan. 24, 1900
LUNDY, AYRES DERBY, Sargent & Lundy, 1720 Railway Exchange Building, Chicago, Ill.	A Feb. 27, 1903 M July 28, 1903
LYMAN, JAMES, Engineer, Western District, General [Life Member.] Electric Co., Monadnock Bldg., Chicago.	A Sep. 19, 1894 M Jan. 9, 1901
MACCOUN, ANDREW ELLICOTT, Supt. Electrical Dept., The Carnegie Steel Co., Braddock, Pa.	A Nov. 20, 1895 M July 18, 1899

MAGNUSSON, CARL EDWARD, Assoc. Prof. of Electrical Engineering, Univ. of Washington, Seattle, Wash.	A Mar. 24, 1905 M Apr. 26, 1907
MAHONY, JAMES J., Engineer General Electric Co., 44 Broad St., New York City.	A May 17, 1898 M July 25, 1902
MAILLOUX, C. O. *E. E., M. S.*, Consulting Electrical [Life Member.] Engineer 76 William St., N. Y.	A Apr. 15, 1884 M Oct. 21, 1884
MANSFIELD, ARTHUR N., Amer. Tel. & Tel. Co., 15 Dey St., New York City.	A Dec. 20, 1893 M June 20, 1894
MARKS, LOUIS B., *M.M.E.*, Electrical Engineer, 220 Broadway; res., 100 Hamilton Place, New York.	A May 20, 1890 M Jan. 16, 1895
MARKS, WILLIAM DENNIS, *Ph.B., C.E.*, Consulting Engineer, 623 Park Row Bldg., New York City.	A Feb. 7, 1888 M May 1, 1888
MARSHALL, J. T., Asst. Engineer, Lamp Works; General Electric Co., Harrison; res., Metuchen, N. J.	A Oct. 1, 1889 M Nov. 12, 1889
MARTIN, JULIUS, Master Electrician, Navy Yard, Brooklyn; res., 445 W. 21st St., New York City.	A Oct. 21, 1890 M Nov. 20, 1895
MARVIN, HARRY N., President American Mutoscope and Biograph Co., 703 Times Bldg., New York.	A Apr. 19, 1892 M Jan. 17, 1893
MATTHEWS, CHARLES P., Prof. Electrical Engineering, Purdue University, Lafayette, Ind.	A May 16, 1893 M Oct. 27, 1905
MAVER, WILLIAM, JR., Consulting Electrical Engineer, 136 Liberty St., New York City.	A July 12, 1887 M Apr 21, 1891
MAVOR, HENRY ALEXANDER, Managing Director, Mavor and Coulson, Ltd., Glasgow, Scotland.	A Dec. 18, 1903 M Feb. 26, 1904
MAYER, GEORGE M., Mechanical and Electrical Engineer, 113 E. Franklin St., Elkhart, Ind.	A Dec. 16, 1890 M June 20, 1894
MAYNARD, GEO. C., Electrical Engineer, Smithsonian Institution, Washington, D. C.	A Apr. 15, 1884 M Dec. 9, 1888
McBERTY, FRANK R., Western Electric Co., New York City	A Apr. 26, 1901 M Mar. 24, 1905
McCAY, H. KENT, Prest., McCay Engineering Co., 9 E. Lexington St., Baltimore, Md.	A Sep. 16, 1890 M May 19, 1891
McCROSKY, JAMES W., J. G. White & Co., Ltd., 22a College Hill, Cannon St., E. C., London, Eng.	A Dec. 20, 1893 M Dec. 16, 1896
McCROSSAN, J. A., City Electrical Engineer; res., 1900 Comox St., Vancouver, B. C	A Oct. 18, 1893 M Dec. 18, 1895
McCULLOCH, RICHARD, United Railways Co., St. Louis, Mo.	A June 15, 1904 M July 26, 1907
McMEEN, S. G., Engineer, 1454 Monadnock Building, Chicago, Ill.	A Dec. 18, 1895 M Dec. 16, 1896
MEREDITH, WYNN, Electrical Engineer, 910 Union Trust Building, San Francisco.	A Jan. 17, 1893 M Nov. 20, 1903
MERSHON, RALPH D., Consulting Engineer, Room 2504, 60 Wall St., New York City.	A Mar. 20, 1895 M Jan. 22, 1896
MILLER, THOMAS LODWICK, Partner, Miller & Wilson, 7 Tower Buildings, Water St., Liverpool, Eng.	A Nov. 20, 1903 M Aug. 17, 1904
MILLIS, JOHN, Major of Engineers, War Department, Washington, D. C.	A July 7, 1884 M Mar. 3, 1885
MITCHELL, JAMES, Rio de Janeiro Tramway, Light & [Life Member.] Power Co., Ltd., Rio de Janeiro, S. A.	A Sep. 25, 1895 M Mar. 25, 1896
MIX, EDGAR W., Electrical Engineer, 12 Boulevard des Invalides, Paris, France.	A Sep. 3, 1889 M Mar. 20, 1895
MOLÉ, HARVEY EDWARD, Chief Engineer Russian Westinghouse Co., St. Petersburg, Russia.	A Nov 30, 1897 M Sep. 27, 1901

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MOLERA, E. J., Civil and Electrical Engineer, 2025 Sacramento St., San Francisco, Cal.	A Jan. 16, 1892 M June 7, 1892
MOORE, D. MCFARLAN, Inventor, Moore Electrical Co., 169 Malvern St., Newark, N. J.	A Dec. 20, 1893 M June 20 1894
MOORE, WM. E., General Supt. and Electrician, P., McK. & C. Ry. Co., Connellsville, Pa.	A Jan. 22, 1896 M Sep. 27, 1899
MORROW, JOHN THOMAS, 24 Broad St., New York City.	A Dec. 21, 1892 M Apr. 18, 1894
MORSE, GEORGE HART, Professor of Electrical Engineering, University of Nebraska, Lincoln, Neb.	A Feb. 23, 1906 M May 14, 1906
MOSES, PERCIVAL ROBERT, *E. E.*, Electrical Engineer, 320 Fifth Ave., New York City.	A Dec. 19, 1894 M Jan. 27, 1905
MURALT, CARL L., Electrical Engineer, 114 Liberty St., New York City.	A May 15, 1900 M Nov. 22, 1901
MURPHY, JOHN, Superintendent Power Houses, The Ottawa Electric Co., Ottawa, Ont.	A May 15, 1900 M Apr. 26, 1901
MURRAY, THOS. E., Second V. P. and General Manager, Edison Co., 55 Duane St., New York City.	A May 21, 1901 M Sep. 26, 1902
MURRAY, WILLIAM SPENCER, Electrical Engineer, N. Y. N. H. & H. R. R. Co., New Haven, Conn.	A Jan. 23, 1903 M Oct. 27, 1905
MUSCHENHEIM, FREDK. A., Electrical Engineer, Hotel Astor, New York City.	A Apr. 27, 1898 M Sep. 27, 1901
NEILER, SAMUEL G., Pierce, Richardson & Neiler, 1405 Manhattan Bldg., Chicago, Ill.	A Apr. 18, 1894 M Dec. 18, 1895
NEWMAN, FRED JACOB, Supt. & Chief Engineer, Woods Motor Vehicle Co., 110 E. 20th St., Chicago, Ill.	A Sept. 27, 1901 M July 26, 1907
NICHOLS, EDWARD L., Professor of Physics, Cornell University; res., 5 South Ave., Ithaca, N. Y.	A Oct. 4, 1887 M Dec 6, 1887
NICHOLSON, WALTER W., General Manager, Central N. Y. Tel. & Tel. Co., Syracuse, N. Y.	A May 15, 1894 M May 18, 1897
NORRIS, HENRY HUTCHINSON, Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.	A Feb. 27, 1903 M Aug. 25, 1905
NUNN, PAUL N., Chief Engineer, Telluride Power Co., Provo, Utah.	A Apr. 17, 1895 M Feb. 26, 1896
O'DEA, MICHAEL TORPEY, 79 No. State St., Chicago, Ill.	A June 8, 1887 M Mar. 25, 1896
OUDIN, MAURICE A., Electrical Engineer, General Electric Co., Schenectady, N. Y.	A June 20, 1894 M Nov. 20, 1895
OWENS, ROBERT BOWIE, [*Local Honorary Secretary*] McDonald Prof. E. Eng., McGill Univ., Montreal.	A June 17, 1890 M Dec. 15, 1897
PACKARD, GRANVILLE FREDERICK, Electrical Engineer, Westinghouse E. & Mfg. Co., Pittsburg, Pa.	A Sep. 26, 1902 M July 28, 1903
PAINE, F. B. H., V.-P. & Chief Engineer, Iroquois Construction Co., Fidelity Building, Buffalo, N. Y.	A Dec. 16, 1890 M Nov. 25, 1891
PAINE, SIDNEY B., General Electric Co., 84 State St., Boston, Mass.	A June 8, 1887 M Nov. 1, 1887
PARKER, LEE HAMILTON, Electrical Engineer, Stone & Webster, Eng'g Corp. 84 State St., Boston, Mass.	A Aug. 5, 1895 M Dec. 16, 1896
PARKS, C. WELLMAN, Civil Engineer, U. S. N., Navy Yard, Portsmouth, N. H.	A July 12, 1887 M May 1, 1888
PARSHALL, HORACE FIELD [*Local Honorary Secretary*], Consulting Engineer, Salisbury House, London.	A Sep. 7, 1888 M Mar. 18, 1890
PATCHELL, WILLIAM HENRY, Consulting Engineer, Caxton House, Westminster, S.W., London, Eng.	A Dec. 15, 1905 M Mar. 23, 1906

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Pattison, Frank A., Consulting & Constructing Electrical Engineer, Fuller Building, New York City.	A Sep. 22, 1891 M Dec. 16, 1891
Pearson, F. S., Engineer, 25 Broad St., New York City.	A Oct. 25, 1892 M Feb. 21, 1893
Pearson, Walter Ambrose, Electrical Engineer, Electrical Development Co., Niagara Falls, Ont.	A Apr. 23, 1903 M Nov. 20, 1903
Peck, John Sedgwick, Electrical Designer, Br. Westinghouse E. & M. Co., Manchester, Eng.	A Apr. 26, 1899 M May 15, 1900
Pedersen, Frederick Malling, *E.E.*, *Sc.D.*, Instructor in Mathematics, College City of N. Y., New York.	A Sep. 20, 1893 M June 24, 1898
Peirce, Arthur W. K., Consulting Electrical Engineer Victoria Falls P. Co., Ltd., Germiston, Trans.	A June 27, 1895 M Aug. 25, 1905
Perkins, Charles Albert, Professor, University of Tennessee, 1547 W. Clinch Ave., Knoxville, Tenn.	A Feb. 24, 1905 M Aug. 25, 1905
Perkins, Jay H., Wilkesbarre Gas and Electric Co., Wilkesbarre, Pa.	A Nov. 21, 1902 M Dec. 15, 1905
Perot, L. Knowles, President Lower Merion St. Ry. Co., 2129 Land Title Building, Philadelphia.	A Mar. 15, 1892 M Dec. 18, 1895
Perrine, Frederic A. C., *D.Sc.*, Consulting Engineer, 60 Wall St., New York City.	A Sep. 16, 1890 M Dec. 16, 1890
Perry, John, Royal College of Science, South Kensington, 34 Palace Gardens Terrace, London, Eng.	A Mar. 22, 1901 M June 28, 1901
Perry, Leslie Lawrence, Electrical Engineer, with F. S. Pearson, 25 Broad St., New York City.	A Mar. 27, 1903 M Mar. 29, 1907
Pestell, William, President, Worcester Steel Foundry Co., Millbury, Mass.	A Apr. 23, 1903 M Feb. 23, 1906
Pfeiffer, Alois, J. J., General Manager, Calcutta Tramways Co., Ltd., Calcutta, India.	A Jan. 24, 1900 M Oct. 26, 1906
Pickernell, F. A. Engineer, Amer. Telephone and Telegraph Co., 125 Milk St., Boston, Mass.	A Feb. 7, 1890 M Mar. 18, 1890
Pierce, Richard H., 140 State St., Room 900, Boston; res., 16 Revere St., Jamaica Plain, Mass.	A Apr. 18, 1893 M Dec. 20, 1893
Pike, Clayton W., *B.S.*, Electrical Engineer, Keller-Pike Co. 1312 Race St., Philadelphia, Pa.	A Dec. 16, 1891 M Oct. 25, 1892
Pikler, Armin Henry, Engineer, Crocker-Wheeler Co., Ampere, N. J.	A Mar. 27, 1903 M Oct. 26, 1906
Pinkerton, Andrew, Commercial Engineer, 1302 Farmers' Bank Building, Pittsburg, Pa.	A Sep. 25, 1895 M June 28, 1901
Poole, Cecil P., Editor *Power*, 499 Pearl St., New York City.	A Jan. 3, 1888 M July 25, 1902
Poole, Charles Oscar, Nevada Power M. & M. Co., Tonopah, Nevada.	A Jan. 24, 1900 M May 19, 1903
Porter, Joseph F., *C.E.*, President Davenport Gas and Electric Co., Davenport, Iowa.	A Sep. 6, 1887 M Nov. 1, 1887
Potter, Henry Noel, *Sc.D.*, 510 West 23d St., New York City; res., 195 Elm St., New Rochelle, N. Y.	A Sep. 19, 1894 M Dec. 19, 1902
Potter, Wm. Bancroft, Engineer Railway Dept., General Electric Co., Schenectady, N. Y.	A Jan. 22, 1896 M Mar. 25, 1896
Pratt, Robert J., Electrician, Honolulu Iron Works, Honolulu, H. I.	A July 12, 1887 M Sep. 6, 1887
Pratt, William Hemmenway, Designing Engineer, General Electric Co. Lynn, Mass.	A Jan. 3, 1902 M July 19, 1904

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PROUTT, FREDERICK GEORGE, Electrical Engineer, Jackson Electric Railway, Lt. & P Co., Jackson, Miss.	A May 19, 1903 M Jan. 29, 1904
PUFFER, WM. L., Electrical Engineer and Expert, 307 Equitable Building, Boston, Mass.	A Dec. 20, 1893 M Apr. 17, 1895
PUTNAM, H. ST. CLAIR, Associate Engineer, L. B. Stillwell, 100 Broadway, New York City.	A Mar. 24, 1905 M Jan. 25, 1907
RANDOLPH, L. S., Professor of Mechanical Engineering, Blacksburg, Va.	A Feb. 21, 1893 M Mar. 1, 1907
RAU, OTTO MARTIN, Chief Electrician, Milwaukee Electric Railway and Light Co., Milwaukee, Wis.	A Feb. 27, 1903 M Oct. 26, 1906
REBER, HENRY LINTON, Sec'y and Chief Engineer, Kinloch Tel. Co., Century Building, St. Louis, Mo.	A May 19, 1903 M Dec. 18, 1903
REBER, SAMUEL, Lieut.-Col., U. S. A., Headquarters Div. of the Philippines, Manila, P. I.	A Sep. 20, 1893 M Jan. 22, 1896
RECKENZAUN, FREDERICK, Electrical Engineer, 77 Chambers St., New York City.	A Mar. 6, 1888 M June 5, 1888
REED, WILLIAM EDGAR, Designing Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburg, Pa.	A Oct. 28, 1904 M Jan. 27, 1905
REID, THORBURN, Consulting Electrical Engineer, 225 5th Ave., New York City.	A Oct. 21, 1890 M June 24, 1898
REIST, HENRY G., Designing Engineer, General Electric Co., Schenectady, N. Y.	A June 17, 1890 M Dec. 19, 1894
RENO, C. STOWE, Electrical Engineer, Triumph Electric Co., 610 Baymiller St., Cincinnati, Ohio.	A Nov. 23, 1898 M July 18, 1899
RICE, CALVIN WINSOR, Sec'y A. S. M. E., 29 West 39th St., New York City.	A Jan. 20, 1897 M Apr. 28, 1897
RICE, E. WILBUR, JR., Technical Director, The General Electric Co., Schenectady, N. Y.	A Dec. 6, 1887 M Jan. 3, 1888
RICHARDSON, ROBERT E., General Manager, K. C. Electric Light Co., Kansas City, Mo.	A Sep. 19, 1894 M May 18, 1897
RICHEY, ALBERT S., Asst. Professor, Worcester Polytechnic Institute, Worcester, Mass.	A May 18, 1897 M June 15, 1904
RIDER, JOHN HALL, Chief Electrical Engineer, London County Council Tramways, London, S. E., Eng.	A Nov. 24, 1905 M May 14, 1906
RIES, ELIAS E., Electrical Engineer and Inventor, 116 Nassau St.; res., 4 W. 115th St., New York City.	A July 12, 1887 M Sep. 6, 1887
RIGGS, WALTER MERRITT, Prof. Electrical Engineering, Clemson Ag. Col., Clemson College, S. C.	A Apr. 22, 1904 M Apr. 27, 1906
RIKER, ANDREW L., Electrical Engineer, Locomobile [Life Member.] Co., of America, Bridgeport, Conn.	A Nov. 1, 1887 M Dec. 18, 1895
ROBB, RUSSELL, Partner Stone & Webster, Engineering Corporation, 84 State St., Boston, Mass.	A Oct. 18, 1893 M May 21, 1895
ROBB, WM. LISPENARD, Prof. Physics and Electrical Engineering, Rensselaer Poly. Inst., Troy, N. Y.	A Dec. 16, 1891 M Mar. 15, 1892
ROBERTS, E. P., E. P. Roberts & Co., Consulting Engineers, Schofield Building, Cleveland, Ohio.	A Jan. 6, 1885 M Feb. 3, 1885
ROBERTSON, ROBERT, Partner, John Strain, M. Inst. C. E., 154 West George St., Glasgow, Scotland.	A Jan. 23, 1903 M Apr. 24, 1903
ROBINSON, DWIGHT PARKER, Vice President, Stone and Webster Engineering Corporation, Boston, Mass.	A Sept. 25, 1895 M July 19, 1904

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ROEHL, CHARLES EDWARD, Electrical Engineer, B.R.T. Co., 168 Montague St., Brooklyn, N. Y.	A Jan. 23, 1903 M May 14, 1906
ROHRER, ALBERT L., Electrical Supt., Schenectady Works, General Electric Co., Schenectady, N.Y.	A Nov. 1, 1887 M May 1, 1888
ROLLER, FRANK W., *M.E.*, Electrical Engineer, Machado & Roller, 203 Broadway, New York.	A May 21, 1895 M Sep. 27, 1901
ROLLER, JOHN E., Capt. U. S. N. (retired) U. S. Navy Yard; res., 101 Munn Ave., East Orange, N. J.	A Sep. 19, 1894 M May 19, 1896
ROSA, EDWARD B., Physicist, National Bureau of Standards, Washington, D. C.	A Feb. 17, 1897 M May 18, 1897
ROSENBUSCH, GILBERT, Queen Anne's Chamber, Westminster, London, S. W., Eng.	A Sept. 28, 1898 M July 19, 1904
ROSS, NORMAN N., Electrical Engineer, General Electric Co., Perin Building, Cincinnati, Ohio.	A Sep. 20, 1893 M Nov. 21, 1894
ROSS, ROBERT A., Mechanical and Electrical Consulting Engineer 78 St. Francis Xavier St., Montreal.	A Sep. 27, 1892 M Apr. 18, 1893
ROUQUETTE, WILLIAM F. B., Proprietor, Rouquette & [Life Member.] Co., 47 Warren St., New York City.	A Mar. 21, 1894 M Dec. 19, 1894
ROWE, BERTRAND PERRY, Detail Engineering Office, Westinghouse E. & M. Co., Pittsburg, Pa.	A Oct. 20, 1903 M July 28, 1905
ROWE, GEORGE HERBERT, Consulting Electrical Engineer, 1211 Fisher Building, Chicago, Ill.	A Jan. 23, 1903 M July 28, 1903
ROWE, NORMAN, General Superintendent, Guanajuato Power and Electric Co., Guanajuato, Mexico.	A Dec. 23, 1904 M Oct. 27, 1905
RUSHMORE, DAVID B., Railway Engineering Department, General Electric Co., Schenectady, N. Y.	A Sep. 25, 1895 M Jan. 24, 1902
RYAN, HARRIS J., Professor of Electrical Engineering, Stanford University, Cal.	A Oct. 4, 1887 M Apr. 17, 1895
SACHS, JOSEPH, President The Arknot Co., 618 Capitol Ave.; res., 4 Cone St., Hartford, Conn.	A Mar. 15, 1892 M Dec. 15, 1897
SALOMONS, *Sir* DAVID LIONEL, *Bart.*, *M.A.*, Engineer [Life Member.] 49 Grosvenor St., London.	A Feb. 7, 1888 M May 1, 1888
SAMPSON, F. D., Superintendent Catawba Power Co., Charlotte, N. C.	A Aug. 5, 1896 M Oct. 27, 1897
SANDS, H. S., Consulting and Constructing Electrical Engineer, 1153 Market St., Wheeling, W. Va.	A Feb. 21, 1893 M Nov. 21, 1894
SARGENT, FRANK C., Chief Electrician, Malden Electric Co., Malden, Mass.	A Feb. 26, 1904 M Mar. 23, 1906
SARGENT, WILLIAM D., Vice-Pres., N. Y. & N. J. Tel. Co., 81 Willoughby St., Brooklyn, N. Y.	A Apr. 15, 1884 M Feb. 21, 1894
SCHEFFLER, FREDK. A., Special Representative, The Stirling Co., 111 Broadway, New York City.	A May 16, 1893 M Jan. 26, 1896
SCHMID, ALBERT, 3 Rue Vacqueri Ste Adresse, Havre, France.	A Oct. 21, 1890 M Apr. 17, 1895
SCHOEN, A. M. [*Manager*], Electrician, S. E. Tariff Association, 433 Equitable Building, Atlanta, Ga.	A Sep. 20, 1893 M Dec. 16, 1896
SCHOEPF, THEODORE HANSMANN, Electrical Engineer, 1411 Twenty-first St., N.W., Washington, D. C.	A Mar. 24, 1905 M Oct. 26, 1906
SCHWEDTMANN, FERDINAND, General Supt., Wagner Electric Mfg. Co., 2017 Locust St., St. Louis, Mo.	A Nov. 22, 1899 M Nov. 23, 1900
SCOTT, CHARLES F. [*Past-President*], Consulting Engineer, Westinghouse E. & M. Co., Pittsburg, Pa.	A Apr. 19, 1892 M Jan. 17, 1893
SCOTT, ERNEST KILBURN, Electrical Engineering Department, Sydney University, Sydney, N. S. W.	A Jan. 27, 1905 M Mar. 24, 1905

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SCOTT, JAMES B., Consulting Engineer, Maryland Savings Bank Building, Baltimore, Md.	A Aug. 5, 1896 M May 17, 1898
SETHMAN, GEORGE HENRY, Mechanical and Electrical Engineer, Skinner & Sethman, Denver, Colo.	A Nov. 23, 1900 M June 28, 1901
SEVER, GEORGE FRANCIS, *M. S.*, Prof. of Electrical Engineering, Columbia Univ., N. Y. City.	A Jan. 17, 1894 M May 19, 1896
SHAW, EDWIN C., Mechanical Engineer, The B. F. Goodrich Co.; res., 104 Park St., Akron, O.	A May 17, 1892 M Feb. 27, 1895
SHEA, DANIEL W., Professor of Physics, Catholic University of America, Washington, D. C.	A Dec. 20, 1893 M June 20, 1894
SHELDON, SAMUEL, *A.M., Ph.D.* [*Past-Pres.*], Prof. Physics Life Member.] & E. E., Poly. Institute, Brooklyn, N. Y.	A Dec. 16, 1890 M Oct. 27, 1891
SHELDON, SIDNEY ROBEY, Professor of Electrical Engineering, University of Idaho, Moscow, Idaho.	A Nov. 21, 1902 M Dec. 23, 1904
SHEPARDSON, GEORGE D., Professor of Electrical Engineering, University of Minnesota, Minneapolis.	A Apr. 21, 1891 M Jan. 22, 1896
SINCLAIR, H. A., Electrical Engineer, Tucker Electric Co., 35 South William St., New York City.	A June 17, 1890 M Feb. 26, 1896
SKINNER, CHARLES EDWARD, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa.	A Apr. 26, 1889 M July 28, 1903
SLICHTER, WALTER I., Electrical Engineer, General Electric Co.; res. 7 Glenwood Blvd., Schenectady, N.Y.	A Apr. 25, 1900 M Oct. 23, 1903
SMITH, FRANK E., Consulting and Supervising Electrical Engineer, 183 Jessie St., San Francisco, Cal.	A Sep. 19, 1894 M July 18, 1899
SMITH, FRANK STUART, 265 W. 81st St., New York City.	A Sep. 27, 1892 M Apr. 18, 1893
SMITH, HAROLD BABBITT, Prof. Electrical Engineering, Worcester Polytechnic Inst., Worcester, Mass.	A Nov. 24, 1891 M Apr. 25, 1900
SMITH, JESSE M., Consulting Electrical and Mechanical Engineer, 220 Broadway, New York City.	A Apr. 15, 1884 M June 26, 1891
SMITH, T. CARPENTER, M. R. Mucklé, Jr., & Co., 316 Mariner and Merchant Bldg., Philadelphia, Pa.	A Oct. 27, 1891 M Dec. 16, 1891
SNELL, JOHN FRANCIS CLEVERTON, Consulting Engineer, Caxton House, Westminster, London, Eng.	A Apr. 27, 1906 M Oct. 26, 1906
SPAIN, HARRY GUTHRIE, Electrician to P. O. of Colony, Telegraph & Telephone, Georgetown, Br. Guiana.	A May 19, 1903 M Oct. 26, 1906
SPARKS, CHARLES PRATT, Chief Engineer, The County of London Electric Lighting Co., London, Eng.	A Mar. 22, 1891 M June 28, 1901
SPERRY, ELMER A., Electrical Engineer, 40 Wall St., New York City.	A Apr. 15, 1884 M Feb. 21, 1893
SPINNEY, LOUIS BEVIER, Professor of Physics and Electrical Engineering, Iowa State College, Ames, Ia.	A May 19, 1903 M July 19, 1904
SPRAGUE, FRANK JULIAN [*Past-President*], Consulting Engineer, 20 Broad St., New York City.	A May 24, 1887 M Feb. 17, 1897
SPRINGER, FRANK W., Assistant Professor Electrical Engineering, University of Minn., Minneapolis.	A Nov. 23, 1900 M Apr. 26, 1901
SPRUANCE, WILLIAM CORBIT, JR., Consulting Engineer, DuPont Building, Wilmington, Del.	A Apr. 27, 1906 M Mar. 1, 1907
STANLEY, WILLIAM, Electrical Engineer and Inventor, Great Barrington, Mass.	A Dec. 6, 1887 M Oct. 26, 1898
STANTON, LEROY W., Superintendent of Equipment, The Federal Telephone Co., Cleveland, Ohio.	A Aug. 22, 1902 M Jan. 23, 1903

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Stark, Edgar Everett, Electrical Engineer, Waiporé Falls Electric Co., Dunedin, N. Z.	A Jan. 23, 1903 M Dec. 18, 1903
Stearns, Joel W., President, Mountain Electric Co., Denver, Colo.	A June 20, 1894 M Nov. 20, 1895
Stebbins, Theodore, J. G. White & Co., 43 Exchange Place, New York City.	A July 9, 1889 M June 17, 1891
Steinmetz, Charles P., *A.M.*, *Ph.D.* [*Past-President*], Consulting Eng'r, G. E. Co., Schenectady, N. Y.	A Mar. 18, 1890 M Apr. 21, 1891
Stevens, J. Franklin, President Keystone Electrical Instrument Co., Philadelphia, Pa	A Sep. 19, 1894 M Feb. 28, 1901
Stewart, Robert Stuart, Consulting Electrical Engineer, 814 Penobscot Bldg., Detroit, Mich. :	A Dec. 20. 1896 M May 15, 1900
Stillwell, Lewis B., Consulting Electrical Engineer, 100 Broadway, New York City.	A Apr. 19, 1892 M Nov. 15, 1892
Stitzer, Arthur Bowers, Electrical Engineer, Phila. R. T. Co., 820 Dauphin St., Philadelphia.	A Oct. 24, 1900 M Oct. 26, 1906
Stone, Charles A., With Firm of Stone & Webster, 84 State St., Boston, Mass.	A May 19, 1891 M July 26, 1907
Stone, Charles Waterman, Electrical Engineer, General Electric Co., Schenectady, N. Y.	A Mar. 27, 1903 M Apr. 27, 1906
Storer, Norman Wilson, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa.	A Dec. 18, 1895 M July 28, 1903
Storrs, H. A., Electrical Engineer, U. S. Reclamation Service, Munsey Building, Washington, D. C.	A Mar. 21, 1893 M Jan. 24, 1900
Stott, Henry G., [*President*], Supt. Motive Power, Interborough R.T.Co., 600 W.59th St., NewYork	A Sep. 25, 1895 M Apr. 22, 1896
Strong, Frederick G., Box 959, Hartford, Conn	A Oct. 27, 1891 M July 18, 1899
Stuart, Harve R., Manager, American Telegraphone Co., Wheeling, W. Va.	A Jan. 25, 1901 M Apr. 27, 1906
Sunny, Bernard Edward, Western Manager, General Electric Co., Monadnock Building, Chicago, Ill.	A Feb. 27, 1903 M Nov. 20, 1903
Swenson, Bernard Victor, Secretary, American St. & Inter. Ry. Asso., 29 W. 29th St., New York.	A Feb. 27, 1895 M Mar. 27, 1903
Swinburne, James, Consulting Electrical Engineer, 82 Victoria St., London, Eng.	A Jan 23, 1903 M Mar. 27, 1903
Swinton, Alan Archibald Campbell, Consulting Electrical Engineer, 66 Victoria St., London.	A Mar. 22, 1901 M June 28, 1901
Terry, Charles A., Sec. and Att'y, Westinghouse Elec. & Mfg. Co., 111 Broadway, New York.	A Apr. 5, 1887 M May 17, 1887
Thomas, Benjamin F., Professor of Physics, Ohio State University, Columbus. O.	A June 7, 1892 M Nov. 15, 1892
Thomas, Percy Holbrook [*Manager*], Cooper Hewitt Electric Co., 111 Broadway, New York City.	A Oct. 24, 1900 M Oct. 27, 1905
Thompson, Edward P., Solicitor of Patents and Expert, 39 Cortlandt St., New York City.	A Apr. 15, 1884 M Dec. 3, 1889
Thompson, Warren Ray, J. G. White & Co., 43 Exchange Place, New York City.	A Oct. 24, 1900 M Oct. 26, 1906
Thomson, Elihu [*Past-President*] Electrician, General Electric Co., Lynn, Mass.	A Apr. 15, 1884 M Apr. 21, 1891
Thresher, Alfred A., Consulting Electrical Engineer 29 Broadway, New York City.	A Apr. 22, 1896 M June 24, 1898

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THULLEN, L. H., Electrical Engineer, Union Switch and Signal Co., Pittsburg, Pa.	A Mar. 25, 1904 M Apr. 26, 1907
THURNAUER, ERNST, Managing Director, Thomson-Houston Int. Elec. Co., 10 Rue de Londres, Paris.	A Oct. 14, 1887 M Dec. 6, 1887
TISCHENDORFER, F., Civil-Ingenieur, Elektrotechnisches Bureau, Ottostrasse 11, Berlin, N. W., Ger.	A Apr. 19, 1892 M Nov. 21, 1894
TORCHIO, PHILIP, Chief Electrical Engineer, New York Edison Co., 55 Duane St., New York City.	A June 27, 1895 M June 15, 1904
TOWNLEY, Calvert, M.E. [*Manager*], First Vice-President Consolidated Railway Co., New Haven, Conn.	A Feb. 28, 1901 M July 26, 1907
TRAFFORD, EDWARD W., Consulting ElectricalEngineer, 27 Chamber of Commerce, Richmond, Va.	A Feb. 21, 1894 M Dec. 19, 1894
TURNER, WILLIAM S., E. Engineer, J. G. White & Co., 43 Exchange Place, New York City.	A Dec. 7, 1886 M Oct. 2, 1888
UEBELACKER, CHAS. F., With Ford ,Bacon & Davis, Hackensack, N. J.	A Feb. 7, 1890 M Nov. 15, 1893
UHLENHAUT, FRITZ, JR., Chief Engineer, Pittsburg Railway Co., Pittsburg, Pa.	A May 7, 1889 M Dec. 19, 1894
UPTON, FRANCIS R., *M.S.*, Edison Laboratory; res., 20 High St., Orange, N. J.	A May 17, 1887 M Mar. 15, 1892
VANSIZE, WILLIAM B., Solicitor of Patents, Expert in [Life Member.] Patent Cases, 253 Broadway, New York.	A Apr. 15, 1884 M Oct. 21, 1884
VAN TRUMP, C. REGINALD, Engineer and Manager, Wilmington City Electric Co., Wilmington, Del.	A Feb. 5, 1886 M Feb. 21, 1894
VIELE, MAURICE A., Viele, Cooper & Blackwell, 49 Wall St., New York City.	A Feb. 23, 1906 M Apr. 27, 1906
VON RECKLINGHAUSEN, MAX, 4 Rue Auber, Paris, France.	A Jan. 24, 1902 M Apr. 24, 1903
WADDELL, MONTGOMERY, Consulting Engineer, 1 West 101st St., New York City.	A Feb. 7, 1888 M May 1, 1888
WAGNER, HERBERT, A., Consulting Engineer, 60 Wall St., New York City.	A Sept. 28, 1898 M July 28, 1903
WAIT, HENRY H., Assistant Electrical Engineer, Western Electric Co., Chicgao, Ill.	A Sep. 20, 1893 M June 20, 1894
WALDO, LEONARD, Electrical Engineer, 802 Atlantic Building, 49 Wall St., New York City.	A June 5, 1888 M Dec. 4, 1888
WALL, LOUIS JAMES BENARD, Full Partner, Splatt, Wall & Co., Perth, Western Australia.	A July 26, 1900 M Nov. 23, 1900
WARNER, ERNEST P., Electrical Engineer, Western Electric Co.; res., 402 Belden Ave., Chicago Ill	A Sep. 20, 1893 M June 20, 1894
WATERMAN, F. N., Mechanical and Electrical Engineer, 100 Broadway, New York City.	A Feb. 21, 1893 M June 20, 1894
WATERS, WILLIAM LAWRENCE, Chief Engineer, National Electric Co., Milwaukee, Wis.	A Oct. 24, 1902 M Aug. 25, 1905
WEAVER, W. D., Editor, *Electrical World*, 239 W. 39th St., N. Y. City; res. Englewood, N.J.	A May 17, 1887 M May 17, 1887
WEBB, A. CLEMENT FREDERICK, Consulting Electrical Engineer, 82 Pitt St., Sydney, N. S. W.	A Nov 25, 1904 M May 14, 1906
WEBB, HERBERT LAWS, Consulting Engineer, 35 Old Queen St., Westminster London, Eng.	A Oct. 21, 1890 M Dec. 16, 1890
WEBSTER, EDWIN S., Firm of Stone & Webster, 84 State St., Boston, Mass.	A Apr. 21, 1891 M July 26, 1907

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Weeks, Edwin R., Consulting Engineer, 606 New Nelson Building, Kansas City, Mo.	A Sep. 6, 1887 M Nov. 1, 1887
Weller, Harry W., Electrical Engineer, Room 1, New York Life Building, Montreal, Que.	A Oct. 21, 1890 M Nov. 24, 1891
Wells, George Augustus, Jr., Chief Engineer, Adams Express Co., 61 Broadway, New York City.	A Apr. 28, 1905 M Sept. 28, 1906
Weston, Edward [*Past-President*], President, Weston Electrical Instrument Co., Waverley Park, N. J.	A Apr. 15, 1884 M Oct. 21, 1884
Wetzler, Joseph, President, Electrical Engineer Institute, 240 W. 23d St., New York City.	A Apr. 15, 1884 M Dec. 9, 1884
Wharton, Chas. J., Palace Chambers, Westminster, London, Eng.	A Jan. 3, 1888 M May 1, 1888
Wheeler, Schuyler Skaats, *Sc. D.* [*Past-President*], [Life Member.] Pres., Crocker-Wheeler Co., Ampere, N.J.	A June 2, 1885 M Sep. 1, 1885
White, James Gilbert, [*Vice-President*] President J. G. White & Co., 43 Exchange Pl., New York City.	A Apr. 2, 1889 M May 15, 1900
White, Will F., Electrical Engineer, The North American Co., 30 Broad St., New York City.	A Feb. 7, 1890 M July 27, 1898
Wiener, Alfred E., Chief Instructor, Electrical Engineer Institute, 240 W. 23d St., New York City.	A May 16, 1893 M May 15, 1894
Wightman, Merle J., Electrical Engineer, 302 Broadway, New York City.	A Mar. 5, 1889 M May 19, 1903
Wilcox, Norman T., Manager, The Lowell Electric Light Corporation, Lowell, Mass.	A May 21, 1895 M Jan. 22, 1896
Willis, Edward J., President, Richmond Electric Co., P. O. Box 164, Richmond, Va.	A Nov. 30, 1897 M Feb. 28, 1900
Wilmerding, Charles Henry, Consulting Elec. and Mechanical Engineer, 84 Van Buren St. Chicago.	A Apr. 22, 1904 M July 19, 1904
Wilson, Charles H, General Supt., American Telephone & Tel. Co., 15 Dey St., New York City.	A Nov. 24, 1891 M Feb. 16, 1892
Wilson, Fremont, Electrical Engineer, Room 310, 34 Pine St., New York City.	A Mar. 6, 1888 M June 5, 1888
Wilson, Howard S., Commercial Engineer, New England Engineering Co., 31 Main St., Waterbury, Ct.	A Aug. 23, 1899 M Feb. 28, 1902
Winchester, A. E., Consulting Engineer for Municipalities, 4 Gerard Pl., South Norwalk, Conn.	A June 8, 1887 M Nov. 1, 1887
Winslow, George Herbert, 1718 Frick Building, Pittsburg, Pa.	A Apr. 17, 1895 M Feb. 26, 1896
Wirt, Herbert C., President, Wirt Mfg. Co., So. Hanson, Mass.	A June 26, 1891 M Oct. 26, 1906
Wolcott, Townsend, Electrical Engr., U. S. Signal Corps, 39 Whitehall St., New York.	A Mar. 6, 1888 M Dec. 16, 1890
Wolverton, B. C., Chief Engineer, 321 Montgomery St., Syracuse, N. Y.	A Mar. 18, 1890 M Feb. 21, 1895
Wood, Benjamin Franklin, Asst. Engineer, Motive Power Department, P. R. R., Altoona, Pa.	A July 28, 1903 M July 26, 1907
Wood, George Roy, Consulting Electrical Engineer, 1207 Park Building, Pittsburg, Pa.	A June 14, 1905 M Mar. 1, 1907
Woodward, Wm. Carpenter, Electrical Engineer, Narragansett Elec. Lighting Co., Providence, R.I.	A Nov. 18, 1896 M Apr. 25, 1902
Wordingham, Chas. H., Electrical Engineer-in-Chief to the British Navy, London, England.	A July 27, 1898 M Oct. 26, 1898
Wotton, James A., Chief Engineer, Electric Mfg. and Equipment Co., 12 St. Charles Ave., Atlanta, Ga.	A Oct. 27, 1897 M Feb. 28, 1901

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WURTS, ALEXANDER JAY, Professor of Applied Electricity, Carnegie Technical Schools, Pittsburg, Pa.	A Apr. 19, 1892 M Nov. 15, 1892
YOUNG, C. GRIFFITH, Engineer Construction, J. G. White & Co., 43 Exchange Place, New York.	A Jan. 3, 1889 M Apr. 21, 1891
YOUNG, WALTER DOUGLAS, Electrical Engineer, B. & O. R. R., Roland Park, Baltimore, Md.	A Apr. 26, 1899 M Jan. 24, 1900

(3) Members, 546

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ASSOCIATES

Name and Address.	Date of Election
AALL, NICOLAI, 716 Madison St., Seattle, Wash.	April 23, 1903
AANES, OTTO RUTHERFORD, Superintendent, Brookings Light, Heat, and Water Department, Brookings, S. D.	June 21, 1907
ABADIE, EUGENE HILARIAN, E. H. Abadie & Co., Bank of Commerce [Life Member.] Bldg., St. Louis, Mo.	June 14, 1905
ABBEY, FRANK HUMPHREY, Mechanical Engineer, Gifford-Wood Co., Hudson, N. Y.	Sept. 22, 1905
ABBOTT, ARTHUR LAURIE, Superintendent of Construction, W. I. Gray and Co.; res., 406 Oak St. S. E., Minneapolis, Minn.	Oct. 26, 1906
ABBOTT, CHARLES L., District Engineer, Westinghouse E. & M. Co., 716 Board of Trade Building, Boston, Mass.	June 19, 1903
ABBOTT, HENRY, President, Calculagraph Co., 9 Maiden Lane, New York City; res., 32 So. Clinton St., East Orange, N. J.	Apr. 28, 1897
ABBOTT, WILLIAM L., Chief Operating Engineer, Chicago Edison Co., 139 Adams St.; res., 3213 Beacon St., Chicago, Ill.	Oct. 25, 1901
ABELL, HARRY CLINTON, Engineer, American Light & Traction Co., 40 Wall St., New York City.	May 19, 1903
ABELLA, JUAN, Consulting Engineer, Buenos Aires and Belgrano Tramways Co. Belgrano, Buenos Aires, A. R.	Aug. 5, 1896
ABENDROTH, WILLIAM PHILIP, General Railway Signal Co., Rochester, N. Y.	May 19, 1903
ABLETT, CHARLES ANTHONY, Pembroke Lodge, Outram Road, Addiscombe, Surrey, England.	Apr. 23, 1903
ABSHAGEN, WILLIAM, Constructing Engineer, Gould Storage Battery Co., 341 Fifth Ave., New York City.	Sept. 28, 1906
ACKER, CHARLES ERNEST, 1 West 121st St., New York City.	Jan. 23, 1903
ACKER, WALTER H., Electrical Engineer, West Penn Rys. Co., Charleroi, Pa.	Mar. 24, 1905
ACKERMANN, ALEXANDER HENRY, Electrical Engineer, Electric Storage Battery Co., 100 Broadway, New York City.	May 19, 1903
ACKLAND, EUSTACE WILLIAM, Electrical Engineer, National Electrical & Eng. Corporation, 19 Vogel St., Dunedin, N. Z.	Jan. 27, 1905
ADAM, FRED B., Secretary and Manager, Frank Adam Electric Co., 914 Pine St.; res., 2326 Albion Pl., St. Louis, Mo.	May 17, 1904
ADAMS, BENJAMIN CULLEN, General Superintendent, Lincoln Gas & Electric Light Co., Lincoln, Neb.	May 14, 1906
ADAMS, CHARLES FRANCIS, Electrical Engineer, California Gas and Electric Corp., San Francisco, Cal.	June 15, 1904
ADAMS, FRANCIS JOSEPH, Department Electrical Engineering, Worcester Polytechnic Institute, Worcester, Mass.	July 19, 1904
ADAMS, GEORGE FRANCIS, District Engineer, Westinghouse E. & M. Co., Room 1007, New England Bldg., Cleveland, O.	Jan. 23, 1903
ADAMS, HARRY H., Superintendent of Shops, United Railways & Electric Co., Carroll Park Shops, Baltimore, Md.	Apr. 27, 1906
ADAMS, HERBERT HARTER, General Superintendent, Merced Falls Gas & Electric Co., Merced, Cal.	Feb. 27, 1903

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ADAMS, JOHN BELDEN, Manager, Electric Cable Department, Waterbury Co., 69 South St., New York City. Sept. 28, 1906

ADAMS, JULIAN, Electrical Engineer, Pacific Electric Railway Co.; res., 735 Francisco St., Los Angeles, Cal. June 21, 1907

ADAMS, ROBERT WINTHROP, Electrical Engineer, D & W Fuse Co., 156 Melrose St., Providence, R. I. Dec. 28, 1906

ADAMS, ROY HARMON, Assistant Electrical Engineer, Signal Office, U. S. Army, 39 Whitehall St., New York City. Oct. 23, 1903

ADAMS, SPENCER, Electrical Engineer, Inca Mining Co., Tirapata, Peru. Nov. 25, 1904

ADAMS, WILLIS LONGFELLOW, General Manager, Adams Construction Co.; res., 726 Buffalo Ave., Niagara Falls, N. Y. Jan. 24, 1902

ADAMS, WILLIAM EDWARD, Assistant Engineer, Rheostat Engineering Dept., General Electric Co., Schenectady, N. Y. Jan. 26, 1906

ADAMS, WILLIAM W., Secretary, Electric Controller and Supply Co.; res., 58 Knox St., Cleveland, O. Jan. 27, 1905

ADAMSON, DANIEL, Joseph Adamson & Co., Hyde, Eng. Feb. 26, 1896

ADDICKS, LAWRENCE, Superintendent, De Lamar Copper Refining Co., Chrome, N. J. July 25, 1902

ADES, LEWIS HENRY, Testing Laboratory, Chicago Edison Co., 76 Market St., Chicago, Ill. Dec. 28, 1906

ADLER, ALPHONSE A., Electrical Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. July 12, 1900

ADSIT, CHARLES GEORGE, Electrical Engineer, Black Mountain Mining Co., Magdalena, Sonora Mexico. Aug. 25, 1905

AGNEW, CORNELIUS R., 16 William St.; res., 23 West 39th St., New York City. Mar. 21, 1894

AGNEW, JOHN PATTERSON, East McKeesport, Pa. Nov. 20, 1903

AHLM, CHARLES EDWARD FRANS, Consulting Engineer, 614 Caxton Bldg., Cleveland, O. Feb. 27, 1903

AIGELTINGER, ARTHUR, Student, Columbia University; res., 14 Leroy St., New York City. Apr. 27, 1906

AITKEN, KENNETH LYNDWODE, Consulting Electrical Engineer, 1003 Traders Bank Building, Toronto, Ont. July 28, 1903

AITKEN, WILLIAM, Telephone Engineer, British Insulated and Helsby Ltd., Prescot, England. Mar. 29, 1907

AKERS, MILTON KENT, Instructor in Electrical Engineering, Washington Agricultural College, Pullman, Wash. May 14, 1906

AKINS, ULYSSES SAGE, Chief Engineer, Lewiston Water and Power Co., Asotin, Washington. Feb. 26, 1904

ALBIN, HENRY ALLISON, General Manager and Electrical Engineer, Concord Street Railway, Concord, N. H. Mar. 22, 1901

ALBURGER, EDWARD T., JR., Electrical Engineer, Frog & Switch Dept., Pennsylvania Steel Co., Steelton, Pa. July 28, 1903

ALDEN, HERBERT WATSON, Engineer, Timken Roller Bearing Axle Co., Canton, Ohio. Aug. 22, 1901

ALDER, GEORGE WASHINGTON, Student, Polytechnic Institute of Brooklyn; res., 15 Somers St., Brooklyn, N. Y. Nov. 23, 1906

ALEXANDER, GEORGE L., Commercial Engineer, General Electric Co., Schenectady, N. Y. June 18, 1903

ALEXANDER, GEORGE RANDALL, Electrician, Central California Electric Co., 1003 K St., Sacramento, Cal. Nov. 25, 1904

ALEXANDER, HARRY, General Manager and Vice-Prest., Alexander-Chamberlain Electric Co., 25 West 33d St., New York City. Apr. 21, 1891

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ALEXANDERSON, ERNST, Electrical Engineer, General Electric Co.; res., 1218 Union Ave., Schenectady, N. Y. Feb. 26, 1904

ALKINS, ALBERT EDWIN, Foreman, Special Testing Dept., General Electric Co.; res., 296 Boston St., Lynn, Mass. Apr. 24, 1903

ALLARD, ARTHUR, Assistant Engineer Mexican Light and Power Co., San Jose el Real 22, Mexico City, D. F. Mexico. Dec. 28, 1906

ALLCOCK, H., with W. T. Glover & Co., Ldt., Trafford Park, Manchester, Eng. Aug. 17, 1904

ALLEN, ARTHUR ELLIOTT, Assistant Foreman, Meter Test Department, Westinghouse Electric and Mfg. Co., Newark, N. J. Dec. 28, 1906

ALLEN, ALBERT MARK, Consulting Engineer, Suite 1130, Schofield Bldg., Cleveland, Ohio. Nov. 25, 1904

ALLEN, ALBERT P., Central Union Telephone Co., Indianapolis, Ind. July 26, 1900

ALLEN, CLAXTON, EDMONDS, Assistant Engineer, General Electric Co., Schenectady, N. Y. Apr. 22, 1904

ALLEN, CHARLES V., Sales and Electrical Engineer, Westinghouse E. & M. Co., Cadena 19, Mexico D. F. Dec. 23, 1904

ALLEN, CHAUNCEY LOOMIS, General Manager, Utica and Mohawk Valley Railway Co., Utica, N. Y. Feb. 23, 1906

ALLEN, EDWIN WOOD, in Consulting Engineering Department, General Electric Co.; res., 14 Union St., Schenectady, N. Y. Mar. 27, 1903

ALLEN, ELBERT GROVER, Superintendent of Construction, Stone & Webster Eng'g Corp., 84 State St., Boston, Mass. Feb. 26, 1904

ALLEN, GEORGE CONRAD, Div. Plant Supt., N. Y. Telephone Co., 15 Dey St., New York City; res., New Rochelle, N. Y. Jan. 23, 1903

ALLEN, JAMES WALTER, First Electrical Assistant, Boston Elevated Railway Co., 552 Harrison Ave., Boston, Mass. Apr. 27, 1906

ALLEN, WALTER CUMMINGS, Electrical Engineer, District of Columbia, District Building, Washington, D. C. June 24, 1898

ALLEN, WYATT H., Consulting Engineer, 910 Union Trust Building, San Francisco, Cal. Apr. 27, 1898

ALLENSWORTH, HARRY RANDALL [*Local Secretary*], Superintendent of Fire and Police Telegraph, Columbus, Ohio. Feb. 26, 1904

ALMOND, FREDERICK CHARLES, Engineer, North Dakota Independent Telephone Co., Fargo, N. D. Apr. 26, 1907

ALTMAYER, HUGO, Vice-President and Superintendent of Shops, Farnsworth Elec. Works, 724 18th St., San Francisco, Cal. Oct. 26, 1906

ALVERSON, HARRY BARTLETT, Superintendent, Cataract Power and Conduit Co., 718 Fidelity Bldg., Buffalo, N. Y. Oct. 25, 1901

ALVORD, RAYMOND MARTIN, Salesman, General Electric Co., Oakland; res., 2314 Channing Way, Berkeley, Cal. Dec. 28, 1906

AMBLER, NATHAN B., General Foreman of Sub-stations, 1355 Pacific St., Brooklyn, N. Y. June 19, 1903

AMBOS, WALTER P., Demonstrator, Osburn Flexible Conduit Co.; res., 596 Hough Ave., Cleveland, O. Nov. 24, 1905

AMSTUTZ, NOAH STEINER, Research Engineer, 130 Sherman St., Chicago: res., Valparaiso, Ill. Jan. 3, 1902

ANDEREGG, GUSTAVUS ADOLPHUS, Associate Professor of Electrical Engineering, Ohio State University, Columbus, O. July 19, 1904

ANDERSON, CHARLES ERASTUS, Electrical Engineer, American Electrical Works; res., 76 Benefit St., Providence, R. I. Mar. 24, 1905

ANDERSON, COOPER, G neral Superintendent, Colorado Department, The Telluride Power Co., Telluride, Col. Nov. 21, 1902

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ANDERSON, DORSEY CULLEN, Superintendent Electric Construction Co· of Virginia, Richmond, Va. Mar. 24, 1905

ANDERSON, DOUGLAS SMITH, Associate Professor of Electrical Engineering, Tulane University, New Orleans, La. Apr. 26, 1901

ANDERSON, EDWARD H., Designing Engineer, General Electric Co.; res., 3 Avon Road East, Schenectady, N. Y. Apr. 25, 1902

ANDERSON, EMANUEL, Assistant Engineer and Chief Draftsman, Mexican Light & Power Co., Mexico D. F., Mexico. Jan. 25, 1907

ANDERSON, JOHN ROBINSON, Mechanical Engineer and Designer, Stanley G. I. Electric Mfg. Co., Pittsfield, Mass. Jan. 27, 1905

ANDERSON, JOHN VICTOR, Understudy Salesman, Westinghouse Electric and Mfg. Co., Salt Lake City, Utah. Mar. 29, 1907

ANDERSON, PAUL LEWIS, Engineering Department, N. Y. Telephone Co., 18 Dey St., New York City. Oct. 23, 1903

ANDERSON, WILLIAM, Engineer, Cascade Water, Power and Light Co., Cascade, British Columbia. Mar. 25, 1904

ANDERSON, WILLIAM FELL, Superintendent Spier Falls Power Station, Hudson River Electric Power Co., Corinth, N. Y. July 19, 1904

ANDRAE, ROBERT TURNER, Student Testing Department, General Electric Co., Schenectady, N. Y. Aug. 17, 1904

ANDREW, JAMES DHU, Virginia Soapstone Co., Schuyler, Va. Apr. 27, 1906

ANDREWS, HERBERT WOODBURY, Engineer, General Electric Co.; res., 128 Nott Terrace, Schenectady, N. Y. Mar. 23, 1906

ANDREWS, LEONARD, Electrical Engineer, Key Engineering Co., Ltd., Scottish Life Bldgs., Manchester, Eng. July 28, 1903

ANDREWS, WILLIAM C., [*Local Secretary*] Publication Bureau, General Electric Co., Schenectady, N Y. May 21, 1895

ANDRUS, LUCIUS BUCKLEY, Superintendent South Bend Electric Co., South Bend, Ind. May 19, 1903

ANGUS, WILLIAM GRAHAM, Electrical Engineer, The Hamilton Electric Light and Cataract Power Co., Hamilton, Ont. May 19, 1903

ANTHONY, CHARLES CHAPMAN, Assistant Signal Engineer, Pennsylvania R.R., 377 Broad St., Station Philadelphia, Pa. Jan. 25, 1907

ANTHONY, JAMES STOWELL, General Electric Co., 44 Broad St., New York City. Apr. 25, 1902

APPERSON, ALFRED HULL, Electrician, South Eastern Tariff Association, Richmond, Va. Sept. 25, 1903

APPLER, GRAFTON WALL, Electrical Engineer, Lyons, N. Y. Nov. 21, 1902

APPLETON, HENRY WILLIAM, Master Mechanic, Passaic Print Works; res., 335 Lafayette Ave., Passaic, N. J. Mar. 29, 1907

APPLETON, WILLIAM COURTNEY, Crocker-Wheeler Co., Ampere, N. J. Mar. 25, 1904

APPLEYARD, ARTHUR E., Treasurer and Managing Dir., Dayton, Springfield & Urbana Electric Ry. Co., Springfield, Ohio. Aug. 5, 1896

ARCHBOLD, WM. K., Archbold-Brady Co., Greenway Ave., Syracuse, N. Y. June 20, 1894

ARCHIBALD, ERNEST M., Assistant Mechanical Engineer, Dominion Coal Co., Glace Bay, N. S. May 15, 1900

ARD, CHARLES EDGAR, Professor Physics and Electrical Engineering, Miss. A. and M. College, Agricultural College, Miss. May 14, 1906

ARENDT, MORTON, Lecturer in Electrical Engineering, Columbia University; res., 1851 7th Ave., New York City. Jan. 23, 1903

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ARGERSINGER, ROY EDWIN, Electrical Engineer, General Electric Co.; res., 11 University Place, Schenectady, N. Y. May 14, 1906

ARIZPE, JESUS DE VALLE, Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 29, 1907

ARLAND, O. B., 39 Carroll St., Yonkers, N. Y. July 28, 1905

ARMSTRONG, JAMES C., Contracting Engineer, 419 Dooly Bldg., Salt Lake City, Utah. Sept. 28, 1906

ARMSTRONG, JAMES ROBERTS, CHARLTON Transmission Engineer, N. Y. C. & H. R. R.R. Co., New York City. Sept. 26, 1902

ARMSTRONG, RALPH WILLISTON, Designer and Draftsman, Gray Electric Co., 75 Fulton St., New York City. May 14, 1906

ARNOLD, CHESTER HASTINGS, Engineer of Studies and Estimates, N. Y. Telephone Co., 15 Dey St., New York City. Jan. 3, 1902

ARNOLD, LEWIS TRACY, Department Manager, Emerson Electric Mfg. Co., 2030 Washington Ave., St. Louis, Mo. Mar. 1, 1907

ARNOLD, WARD S., Electrical Engineer, Marquette Bldg.; res., 384 E. 40th St., Chicago, Ill. Jan. 24, 1902

ARNSON, LUDWIG, Engineer, Electric Machinery Co., 87 Nassau St.; res., 1452 Lexington Ave., New York City. Feb. 23, 1906

ARUNACHELA, IYER T. K., Superintendent Bangalore Electric Lighting, Bangalore, India. Oct. 28, 1904

ASBURY, ORLA FINGER, Electrical Engineer, D. A. Tomkins Co., 209 S. Myers St., Charlotte, N. C. Mar. 25, 1904

ASH, ALBERT LYNN, Assistant Superintendent, Sta. A, Philadelphia Electric Co.; res., 745 No. 40th St., Philadelphia, Pa. Oct. 26, 1906

ASHBRIDGE, DONALD MACQUEEN, Electrical Engineer, 7111 Chew St., Mt. Airy, Philadelphia, Pa. June 21, 1907

ASHE, SIDNEY WHITMORE, Instructor in Physics, Polytechnic Institute, Brooklyn; res., Webster Ave., Bedford Park, N. Y. June 28, 1901

ASHLEY, FRANK M., *M.E.*, Tribune Building, res., 59 West 105th St., New York City. Nov. 21, 1894

ASPNES, EIVIND A., Engineer and General Manager, Montevideo Electric Light and Power Co., Montevideo, Minn. Sept. 28, 1906

ATKINS, CHARLES GILMAN, Consulting Engineer, Pratt & Atkins, 1001 Monadnock Building, Chicago, Ill. Oct. 25, 1901

ATKINS, DAVID F., Inspector, Electrical Engineer, Supervisor Architects Office, Federal Bldg., Omaha, Neb. Mar. 29, 1907

ATKINS, HAROLD B., Dodge & Day, Room 597 Drexel Bldg., Philadelphia, Pa. June 23, 1897

ATKINSON, THOMAS WILSON, Professor of Physics and Electrical Engineering, Louisiana State University, Baton Rouge, La. June 21, 1907

ATWOOD, GEORGE F., Goodyear Rubber Insulating Co., 105 E. 131st St., New York City. Sept. 16, 1890

AUBL, CARL B., Assistant to Manager of Works, Westinghouse Electric Co., Pittsburg, Pa. July 26, 1900

AUSTIN, ARTHUR OSWIN, General Manager, Lima Insulator Co., Lima, N. Y. Oct. 28, 1904

AUSTIN, SYDNEY B., President, Austin-Smith Engineering Co., Baltimore, Md. Sept. 25, 1895

AUTH, CHARLES, Secretary and Manager, DeVean Telephone Mfg. Co.; res., 893 Decatur St., Brooklyn, N. Y. Mar. 29, 1907

AVERILL, REX GILMAN, Ohio Brass Co., Mansfield, Ohio. Jan. 25, 1907

AVERRETT, ANDREW E., Engineer, General Electric Co.,; res. 934 State St., Schenectady, N. Y. Jan. 3, 1902

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AYLMER-SMALL, SIDNEY, Electrical Engineer, 147 W. 91st St., New York City; res., 11 Randolph St., Passaic, N. J. Oct. 24, 1900

AYLSWORTH, J. WALTER, Experimenter and Chemist, Edison Laboratory; res., 223 Midland Ave., East Orange, N. J. Sept. 27, 1901

AYRES, ALBERT DOANE, Keokuk Electric Railway Co., 421 Main St., Keokuk, Iowa. Feb. 28, 1902

AYRES, MILAN VALENTINE, Electrical Engineer, Boston and Worcester Street Railway Co., South Framingham, Mass. May 19, 1903

BAAB, CHARLES JACOB, 346 So. Main St., Wilkesbarre, Pa. Sept. 22, 1905

BABBITT, HARRY D., Electrical Engineer, Thompson Starrett Co., 51 Wall St.; res., 7 W. 108th St., New York City. Mar. 27, 1905

BABCOCK, EDWIN WILSON, Superintendent of Electrical Construction, Brooklyn Edison Co., Brooklyn, N. Y. Sept. 25, 1903

BABSON, ALBERT D., Manager, Supply Department, General Electric Co., 44 Broad St., New York City. Mar. 27, 1903

BABSON, ARTHUR C., Engineer, General Electric Co., 1006 Alaska Bldg., Seattle, Wash. Mar. 28, 1900

BABTISTE, CARL AUGUSTUS, McGraw Publishing Co., 239 W. 39th St., New York City. Jan. 26, 1906

BACHE-WIIG, JENS, Engineer, Westinghouse Elec. Mfg. Co., Pittsburg, Pa. Oct. 26, 1906

BACHMAN, HARRY LOUIS, [*Local Secretary*] Engineer and Electrician, Dunn Taft & Co.; res., 1231 East Main St., Columbus, O. Apr. 28, 1905

BACKUS, CYRUS DAY, Assistant Examiner, United States Patent Office; res., 1017 P St., Washington, D. C. June 21, 1907

BACON, DANIEL READ, Electrical Engineer, 63 Heights Road, Ridgewood, N. J. July 28, 1903

BACON, ELLIS HATTON, Regulator, New York Edison Co., Waterside Station, New York City. Sept. 28, 1906

BACOT, EUGENE CYRUS, Chief Electrician and Designing Engineer, Bibb Power Co. Apr. 23, 1903

BADEAU, CHARLES CUSHING, The Switchboard Equipment Co., Bethlehem, Pa. Apr. 25, 1902

BAEHR, GEORGE, Chief Electrician, Nat. Tube Co.; res., 516 Willow Ave., McKeesport, Pa. Jan. 23, 1903

BAEHR, WILLIAM ALFRED, Engineer, Laclede Gas Light Co., St. Louis, Mo. Feb. 27, 1903

BAGNALL, E. J., General Manager, Adams, Bagnall Electric Co., 2049 E. 100th St., Cleveland, Ohio. Apr. 26, 1907

BAGOT, CHRISTOPHER GEORGE SEYMOUR, Student, Worcester Polytechnic Institute; res., 214 West St., Worcester, Mass. Apr. 28, 1905

BAILEY, CLIFFORD DEXTER, Student, Polytechnic Institute; res., 861 Carroll St., Brooklyn, N. Y. Mar. 27, 1903

BAILEY, EUGENE TRYON, Electrical Engineer, G. and O. Braniff & Co., Mexico, Mex. May 14, 1906

BAILEY, FRED. W. C., Consulting Engineer, 1005 Wyandotte Bldg., Columbus, Ohio. Feb. 26, 1904

BAILEY, THEO. P., Assistant Manager, Chicago Office, General Electric Co., 1117 Monadnock Bldg., Chicago, Ill. Apr. 25, 1902

BAINS, THOMAS MELLOR, JR., Engineer and Electrician, Rosebush Mining and Leasing Co., Goldfield, Nev Mar. 29, 1907

BAINTON, JOHN RICHARD, Consulting Engineer, Standard Electric Elevator Co., Equitable Bldg., Sydney, N. S. W. Oct. 24, 1902

BAKER, EDWARD STUART, 10 North Church St., Schenectady, N. Y. Apr. 28, 1905

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BAKER, EDWIN STANTON, Electrical Engineer, West Virginia Pulp and Paper Co., Piedmont, W. Va. May 15, 1905

BAKER, FRANK J., Vice-President, North Shore Electric Co., 134 Washington St., Chicago, Ill. Mar. 29, 1907

BAKER, GEORGE A., Assistant District Operating Superintendent, New York Edison Co., 55 Duane St., New York City. Mar. 23, 1906

BAKER, GEORGE OTIS, Mechanical and Electrical Engineer, New England Engineering Co., New York City. Apr. 27, 1906

BAKER, HAROLD PETERS, Student, Massachusetts Institute of Technology, Boston, Mass;. res., White Haven, Pa. Mar. 29, 1907

BAKER, HENRY CLARK, Crocker-Wheeler Co., First St., San Francisco, Cal. Mar. 24, 1905

BAKER, HENRY STEVENSON, Engineer, Ontario Power Co., Niagara Falls South, Ont. Sept. 28, 1906

BAKER, I. FRALEY, Superintendent's Office, Sprague Electric Co.; res., 18 S. Clinton St., East Orange, N. J. June 15, 1904

BAKER, JOSEPH B., Technical Editor, Fuel Investigations, 1014 17th St. N. W., Washington, D. C. Sept. 27, 1901

BAKER, PERCY ALBERT, Construction Foreman, General Electric Co., Schenectady, N. Y. Aug. 25, 1905

BAKER, WILLIAM EDGAR, W. E. Baker & Co., Engineers, 27 William St., New York City. June 28, 1901

BALCOMB, JEAN BART., General Manager, Hudson River Concrete Co., 26 Court St., Brooklyn, N. Y. July 28, 1905

BALDWIN, CHARLES FOWLER, Chief Engineer Bell Telephone Mfg. Co., 18 Rue Bondewyns, Antwerp, Belgium. Oct. 23, 1903

BALDWIN, EDWARD ARTHUR, Electrical Engineer, General Electric Co., Schenectady, N. Y. July 26, 1907

BALDWIN, GEORGE PORTER, Vice-president Blaisdell Filtration Co., Douglass Bldg., Los Angeles, Cal. Nov. 23, 1900

BALDWIN, JAS. C. T., American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Apr. 17, 1895

BALFOUR, REGINALD, Asst. Operating Supt., Montreal Light, Heat & Power Co., 150 Park Ave., Montreal, P. Q. Mar. 27, 1903

BALINT, BÉLA, Consulting Engineer, VIII Jozsef kornt 9, Budapesth, Hungary. June 14, 1905

BALL, HENRY PRICE, Electrical Engineer, General Incandescent Arc Light Co., 524 W. 57th St., New York City. May 21, 1901

BALLARD, FREDERICK WAYNE, Mechanical Engineer, Sherwin-Williams Co.; res., 13 Rock Court, Cleveland, Ohio. Feb. 27, 1903

BALLINGER, PHILIPPE FAZIO, Manager, Gas Department Charlotte Consolidated Construction Co., Charlotte, N. C. Apr. 28, 1905

BALSLEY, ABE, Electrical Engineer, 802 Lexington Ave., Indianapolis, Ind. Oct. 27, 1897

BAMBER WILLIAM CHILD, Electrical Engineer, H. W. Johns-Manville Co., 100 William St., New York City. Oct. 25, 1901

BANGHART, CHARLES SCHUYLER, Superintendent Motive Power, N. Y. & Queens Co., Railway Co. Long Island City, N. Y. Aug. 25, 1905

BANGS, CHAS. R., Special Agent, American Telephone and Telegraph Co., 15 Dey St., New York City. Jan. 26, 1898

BANGS, EDWARD HUGH, Engineer, Central Union Telephone Co., Indianapolis, Ind. Apr. 28, 1905

BANGS, GEORGE HAROLD, Student, Brooklyn Polytechnic Institute, Brooklyn, N. Y.; res., 431 W. 162d St., New York City. May 14, 1906

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BANKS, WILLIAM C., Consulting Electrical Engineer, Thomson-Houston Carbon Co., Fremont, Ohio. May 18, 1897

BANNING, THOMAS ALLEN, JR., with board of supervising engineers, Chicago Traction Co., Wheaton, Ill. June 21, 1907

BARBER, EDWIN LAMONT, 4052 West Belle Place, St. Louis, Mo. Mar. 1, 1907

BARBER, IRA WILSON, Superintendent Electric Light and Power Plant, Mount Airy, N. C. Dec. 28, 1906

BARCLAY, GEORGE, New Zealand Volunteers, Palmerston, Otago, N. Z. May 17, 1904

BARKER, GEORGE WILLSEA The Maintenance Co., 54 Franklin St., New York City. Aug. 25, 1905

BARKER, HARRY, Assistant Editor, *Engineering News*, 220 Broadway, New York City. Mar. 24, 1905

BARKER, JAMES EDMUND, Manager, Ventura Water, Light & Power Co., Ventura, Cal. Apr. 23, 1903

BARKER, RALPH EMERSON, Assistant Electrical Engineer, General Electric Co.; res., 24 Chase St., Lynn, Mass. May 19, 1903

BARKER, ROBERT JAY, Electrical Engineer, Westinghouse Electric and Mfg. Co., Ellicott Square, Buffalo, N. Y. Sept. 28, 1906

BARKLEY, JAMES ALLEN, General Manager, Port Elizabeth Electric Tramway Co., Port Elizabeth, South Africa. Sept. 28, 1906

BARNES, DAVID WICKHAM, Selling Engineer, C. & C. Electric Co., 149 Broadway, New York City. Jan. 26, 1906

BARNES, EDWARD A., Electrical Expert, Fort Wayne Electric Co. Fort Wayne, Ind. Sept. 20, 1893

BARNES, RALPH NELSON CARPENTER, Boston Manager, Crocker Wheeler Co.; res., 16 Little Road, Brookline, Mass. Nov. 23, 1906

BARNES, WALTER CLYMER, New York Westchester & Boston Ry. Co., 30 Broad St., New York City. Nov. 20, 1903

BARNES, WELDEN FAIRBANKS, Correspondent, Westinghouse Electric and Mfg. Co., Kansas City, Mo. June 21, 1907

BARNES, WILFRED, JR., Chief Crane Inspector, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Jan. 27, 1905

BARNES, WILLARD J., Electrician, The Duncan Co., Mechanicsville, N. Y. June 19, 1903

BARNETT, CARL P., Engineer, 812 Locust St., Kansas City, Mo. Jan. 25, 1901

BARNHAM, EDMUND KIRBY, Columbia Improvement Co., St. Croix Falls, Wis. July 28, 1905

BARNHART, WILLIAM O., Engineer, Chicago & Oak Park Elevated R.R. Co., 1133 W. Lake St., Chicago, Ill. July 19, 1904

BARNUM, THOMAS EDSON, Assistant Chief Engineer, Cutler-Hammer Mfg., 648 34th St., Milwaukee, Wis. Nov. 20, 1903

BARNWELL, WILLIAM HABERSHAM, Electrical Inspector, South Eastern Tariff Association, Columbia, S. C. Sept. 28, 1906

BARR, JOHN B., Electrical Engineer, General Electric Co., 44 Broad St., New York City. Apr. 25, 1900

BARR, JOHN MARTIN, Engineering Salesman, Westinghouse Electric & Mfg. Co.; res., 260 Shady Ave., Pittsburg, Pa. Oct. 27, 1905

BARRETT, JOHN ARNOLD, Electrical Engineer, American Telephone and Telegraph Co., 15 Dey St., New York City. Jan. 27, 1905

BARRETT, WILLIAM ALEXANDER, Meter Inspector, Missoula Light and Water Co., Missoula, Mont. June 21, 1907

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BARROWS, WILLIAM EDWARD, JR., Instructor, Electrical Engineering, Armour Institute of Technology, Chicago, Ill. June 21, 1907,

BARRY, CHARLES EDWARD, Electrical Engineer, General Electric Co. Schenectady, N. Y. Sept. 25, 1903

BARRY, DAVID, Electrician and Superintendent, Amherst Gas Co., Amherst, Mass. Aug. 5, 1896

BARRY, JOHN C., Testing Department, General Electric Co., Schenectady, N. Y. Jan. 27, 1905

BARRY, JOHN G., General Electric Co., Schenectady, N. Y. Apr. 23, 1903

BARSTOW, WILLIAM AUGUSTUS, Superintending Electrical Engineer, Union Iron Work Co., San Francisco, Cal. Apr. 26, 1907

BARTH, MAX RICHARD, Hagelbergerstr. 47 IV, Berlin, S. W. 47, Germany. May 15, 1905

BARTLETT, ENOCH JOSEPH, Assistant Engineer, Electric Vehicle Co.; res., 231 New Britain Ave., Hartford, Conn. June 21, 1907

BARTON, CHARLES ARTHUR, District Sales Manager, Nernst Lamp Co., 11 Pine St.; res., 145 W. 105th St., New York City. Jan. 29, 1904

BARTON, EDWARD JAMES, Assistant Electrical Engineer, Panama Railroad Co. and Electric Light Co., Panama R. de P. Oct. 28, 1904

BARTON, ENOS M., President Western Electric Co., 259 So. Clinton St., Chicago, Ill. July 12, 1887

BARTON, GEORGE LEWIS, Erecting Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Oct. 28, 1904

BARTON, ROBERT CHARLES, Seattle Electric Co.; res., 226 Boren Ave., North, Seattle, Wash. May 14, 1906

BASCH, DAVID, Switchboard Engineer, General Electric Co., Schenectady, N. Y. Mar. 29, 1907

BASSETT, NORMAN CHAUNCEY, Consulting Engineer, Allis-Chalmers Co., Milwaukee, Wis. Aug. 25, 1905

BATEMAN, GEORGE FREDERICK, Student, Cooper Union Day School of Technical Science, New York City. Apr. 26, 1907

BATES, FRANCIS REED, Consulting Engineer, Bogart-Bates Co., 508 Pacific Block, Seattle, Wash. May 17, 1904

BATES, FREDERICK C., Electrical Engineer, General Electric Co., 44 Broad St., New York City. Jan. 20, 1891

BATES, GEORGE MOULTON, Sales Agent, Westinghouse Electric and Mfg. Co., 716 Board of Trade Bldg., Boston, Mass. July 19, 1904

BATES, LOUIS W., Atlantic Coast Electric Railway, Asbury Park, N. J. Mar. 25, 1904

BATES, PUTNAM A., Consulting Electrical Engineer, 42 Broadway; res., 12 Fifth Ave., New York City. Jan. 20, 1897

BATHGATE, OWEN HAMILL, Mechanical Assistant, P. N. Y. & L. I. R.R. Co. Power Station, Long Island City, N. Y. Apr. 26, 1907

BATSON, WALTER VENNARD, Electrical Engineer, Hollis French and Allen Hubbard, Boston; res., 12 Pratt St., Allston, Mass. June 15, 1904

BATT, WILLIAM HARPER, JR., Laboratory Assistant, Drexel Institute, Philadelphia, Pa. Nov. 23, 1906

BATTEY, PAUL LEON, Electrical Engineer, The Arnold Co., Borland Bldg., 181 La Salle St., Chicago, Ill. Dec. 19, 1902

BAUER, HENRY NICHOLAS, Equipment Department Sunset Telegraph & Telephone Co., Los Angeles, Cal. June 15, 1904

BAUER, WALTER HENRY, Salesman, Ft. Wayne Electric Works, 403 Atlas Bldg., San Francisco, Cal. Dec. 28, 1906

BAUGHER, E. C., Govanstown, Md. Nov. 22, 1899

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Baum, Wilhelm, General Electric Co.; res., 1001 Union St., Schenectady, N. Y. Mar. 24, 1905

Bausch, Frederick Emil, Manager, Hooven, Owens Rentschler Co., 1316 Chemical Bldg., St. Louis, Mo. June 28, 1901

Baylis, James Adams, Electrical Engineer, The Bell Telephone Co., Montreal, P. Q. Sept. 26, 1902

Bayne, Howard, Assistant to Dr. M. I. Pupin, Columbia University, New York City. Sept. 27, 1901

Beach, Howard Lindsley, Designing Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 29, 1907

Beal, Thaddeus R., General Manager, Poughkeepsie Light, Heat and Power Co., Poughkeepsie, N. Y. Mar. 27, 1903

Beals, William Bryant, Block Inspector, Chesapeake and Potomac Telephone Co., 1912 Park Ave., Baltimore, Md. June 21, 1907

Beam, Victor Shaeffer, Electrical Engineer, 48 Carleton St., East Orange, N. J. Oct. 24, 1902

Bean, Harry Joel, Electrical Engineer, California Gas & Electric Corporation, 1782 Post St., San Francisco, Cal. July 28, 1903

Beardslee, Robert Winslow, Engineering Department, J. G. White & Co., 43 Exchange Place, New York City. Mar 1, 1907

Beard, Richard Meek, Chief Engineer, International District Telephone Co., 50 Broadway, New York City. May 14, 1906

Beardsley, Havilah, Sales Agent, Westinghouse Elec. & Mfg. Co., 317 Joplin St., Joplin, Mo. Feb. 23, 1906

Beattie, Mark Brewer, Electrical Engineer, 305 Commercial Bldg., Louisville, Ky. Mar. 29, 1907

Beattys, William Henry, Jr., Westinghouse Electric Mfg. Co., New York Life Bldg., Chicago, Ill. May 19, 1903

Beaubien, Edgar Francis, Patent Department, Western Electric Co., 259 So. Clinton St., Chicago; res., Wilmette, Ill. Apr. 26, 1907

Beauchamp, Leon, Manager and Electrical Engineer, Standard Construction Co., Montreal, Que. Oct. 23, 1903

Beaujon, Anton Rudulof, General Manager, East Coast E. L. P. and Ice Co., West Palm Beach, Fla. Nov. 25, 1904

Becket, Bergie Barry, Ocean Shore Railway Co., 55 Eleventh St., San Francisco, Cal. May 17, 1904

Beckman, Magnus, Consulting Electrical Engineer, Linköping, Sweden. Apr. 28, 1905

Beckstrand, Elias Hyrum, Instructor, Engineering Department University of Utah, Salt Lake City, Utah. Apr. 23, 1903

Beckstrom, John A., Superintendent, Switchboard Department Tri-State Telephone and Telegraph Co.; St. Paul, Minn. June 21, 1907

Beckwith, Edward Pierrepont, Engineer, General Electric Co., Schenectady; res., Garrison, N. Y. June 21, 1907

Beckwith, Robert Stanley, Telephone Engineer, Western Electric Co., North Woolwich, Eng. Feb. 24, 1905

Bedell, Charles Hampton, Head of Laboratory, Electro-Dynamic Co., Bayonne, N. J. May 19, 1903

Bedell, Rayner Monroe, 20 North Mountain Ave., Montclair, N. J. Feb. 27, 1903

Bee, William G., Edison Storage Battery Co., Orange, N. J. Apr. 23, 1903

Beebe, Murray C., Associate Professor of Electrical Engineering, University of Wisconsin, Madison, Wis. Jan. 26, 1898

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BEEUWKES, REINIER, Assistant Engineer, N. Y. C. & H. R. R.R., Electrical Dept. G. C. Station, New York City. Mar. 1, 1907

BEGGS, JOHN IRVIN, President and General Manager, Mil. Electric Railway and Light Co., Milwaukee, Wis. Aug. 17, 1904

BEGOLE, JOSHUA FRANKLIN, Electrical Engineer, Wagner Electric Mfg. Co.,; res. 1406 Euclid Ave., St. Louis, Mo. Sept. 28, 1906

BEHAN, THOMAS WALTER, Electrical Engineer, Fort Wayne Electric Co., Fort Wayne, Ind. Aug. 25, 1905

BEILSTERN, LOUIS EDWARD, General Manager, Toledo Railways and Light Co., Toledo. O. July 26, 1907

BELCHER, WALTER A., Public Service Corporation of N. J., 156 Smith St., Perth Amboy, N. J. Mar. 24, 1905

BELDON, DAVID W., Manager, Westinghouse Electric & Mfg. Co., Santa Rita Bldg., Tucson, Ari. Sept. 26, 1902

BELL, ALONZO C., Owner and Manager, Bell Electric Motor Co., 197 Wooster St.; res., 59 W. 76th St., New York City. Sept. 27, 1901

BELL, HARRY LAYFIELD, Electrical Engineer, Standard Underground Cable Co., Westinghouse Bldg., Pittsburg, Pa. Jan. 25, 1907

BELL, JOHN THOMAS ROBB, Engineer, Universal Battery Co., Dept. 1, 795 E. 52d St., New York City. Apr. 28, 1905

BELL, ORA A., Electrical Engineer, Western Electric Co., 463 West St., New York; res., 352 W. 117th St., New York City. Aug. 5, 1896

BELL, ULYSSES S., Assistant Electrician, South Eastern Tariff Association, Atlanta, Ga. Oct. 28, 1904

BELLMAN, JOHN JACOB, President, Bellman & Sanford, 149 Broadway, New York City. Dec. 28, 1898

BELLOWS, BRIAN CHANDLER, American Telephone & Telegraph Co., Richmond, N. Y. Nov. 24, 1905

BELNAP, LA MONTE, J., District Engineer, Allis-Chalmers-Bullock, Ltd. Sovereign Bank Bldg., Montreal, Que. Apr. 23, 1903

BELT, WILLIAM BRADLEY TYLER, Superintendent, Nebraska Telephone Co., 202 S. 18th St., Omaha, Neb. June 21, 1907

BEMENT, A., Consulting Mining and Mechanical Engineer, American Trust Bldg., Chicago, Ill. Apr. 27, 1906

BENDHEIM, BERTHOLD HERBERT, F. E. Newbery & Co., Century Building, St. Louis, Mo. Sept. 28, 1906

BENDEKE, CARL, Draftsman, New York Edison Co., New York City; res., 280 Henry St., Brooklyn, N. Y. Jan. 25, 1907

BENEDICT, VALLETTE LYMAN, Power and Mining Dept., General Electric Co., Los Angeles, Cal. Feb. 23, 1906

BENEZE, WILLIAM, Chief Electrician, Maryland Telephone Co.; res., 124 Stafford St., Baltimore, Md. June 21, 1907

BENJAMIN, GEORGE R., Electrical Department, Western Union Telegraph Co., 195 Broadway, New York City. July 26, 1907

BENJAMIN, REUBEN B., President Benjamin Electric Mfg. Co.; res., 2046 Gladys Ave., Chicago, Ill. Mar. 1, 1907

BENNET, ORVILLE G., JR., American Trading Co., Yokohama, Japan. May 14, 1906

BENNETT, CHARLES EDWARD, with L. B. Stillwell, 100 Broadway, New York City. June 15, 1904

BENNETT, EDWARD, Electrical Engineer, Telluride Power Co., Provo, Utah. Sept. 27, 1901

BENNETT, EDWARD R., Superintendent, Sayre Electric Co., Sayre, Pa. June 14, 1905

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BENNETT, EDWIN H., JR., Electrician and Engineer, Singer Mfg. Co., Elizabethport, N. J. June 20, 1894

BENNETT, JOHN C., Electrician, General Electric Co., 44 Broad St., New York City. Mar. 18, 1890

BENNETT, RALPH, Consulting Engineer, 136 Witmer St., Los Angeles, Cal. Oct. 23, 1903

BENNETT, WILLARD S., Engineering Department, The S. S. White Dental Mfg. Co., 5 Union Square, West, New York City. Oct. 25, 1901

BENOLIEL, SOL. D., *B.S.*, *E.E.*, *A.M.*, General Manager, International Chemical Co., Camden, N. J. Oct. 21, 1896

BENTLEY, EDWARD M., Patent Attorney and Expert, 120 Broadway, New York City. May 21, 1901

BENTLEY, MERTON H., Electrical Engineer, 930 Flournoy St., Chicago, Ill. Oct. 18, 1893

BENTLEY, WILTON, Universal Electric Storage Battery Co., 36 Union Park Place, Chicago, Ill. July 28, 1903

BERAN, THEODORE, Manager, General Electric Co., 44 Broad St., New York City. July 25, 1902

BERG, EDWIN VICTOR, Draughtsman, Twin Falls, Idaho. Apr. 22, 1904

BERG, ESKIL, Electrical Engineer, General Electric Co., Schenectady, N. Y. Nov. 20, 1895

BERG, GEORGE HEWES, Sales Manager, Berkshire Co., 16 Columbus Ave., Boston; res., Brookline, Mass. Apr. 23, 1903

BERG, MAX A., Secretary, Porter & Berg, 303 Dearborn St., Chicago, Ill. May 19, 1903

BERGELIN, THORSTEN, Assistant Engineer, Utah Light and Railway Co.; res., 571 So. Main St., Salt Lake City, Utah. Apr. 26, 1907

BERGEN, FRANCIS PATRICK, Electrical Engineer, Hotel Dale, 1037 Fillmore St., San Francisco, Cal. June 19, 1903

BERGEN, OTTO, Engineer,' Katalla Co., Katalla, Alaska. Apr. 23, 1903

BERGENDAHL, CHRISTIAN JOHAN GUSTAF, Electrical Inspector, Underwriters' Association, Reading, Pa. Apr. 26, 1907

BERGENTHAL, VICTOR W., Wagner Electric Mfg. Co., 2017 Locust St., St. Louis, Mo. Jan. 9, 1901

BERGMAN, BRODER JULIUS G:son, Electrical Engineer, Elektriska prefning-sanstalten, Stockholm, Sweden. Feb. 24, 1905

BERGMAN, SVEN ROBERT, Assistant Engineer, General Electric Co.; res., 21 Arlington St., Lynn, Mass. Oct. 28, 1904

BERN, EMIL GUSTAVUS, Electrical Engineer, General Electric Co., Schenectady, N. Y. Apr. 26, 1907

BERNAYS, CHARLES EDWIN, Queensland Representative, Noyes Bros., 45 Adelaide St., Brisbane, Queensland. Dec. 18, 1903

BERNHARD, FRANK HUGO, Instructor in Electrical Engineering, Armour Institute of Technology, Chicago, Ill. Apr. 26, 1907

BERNHARDT, DAVID F., Chief Electrician, J. B. King & Co., 402 Richmond Terrace, New Brighton, S. I., N. Y. June 21, 1907

BERNSTEIN, JULIUS, Technical Assistant, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa. Sept. 22, 1905

BERRY, A. HALL, General Manager, 97 Warren St., New York City; res., Montclair, N. J. May 20, 1902

BERRY, CLYDE ALBION, Telephone Engineer, Western Electric Co., 463 West St., New York City. June 15, 1904

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BERRY, EDGAR HENRY, Chief Engineer, Wyckoff Seamans & Benedict, Ilion, N. Y. Apr. 23, 1903

BERRY, EDWARD ROBIE, Chemist, Engineering Laboratory, General Electric Co., Lynn; res., 107 Cross St., Malden, Mass. Jan. 25, 1907

BERRY, MAXWELL RUFUS, Manager, Southern Brass Works, Atlanta, Ga. Nov. 25, 1904

BERRY, WILLIAM JOHNSTON, Instructor in Mathematics, Brooklyn Polytechnic Institute; res., 1937 83d St., Brooklyn, N. Y. Mar. 29, 1907

BERY, AMAR NATH, Testing Department, General Electric Co., Ltd.; 53 Kingsbury Road, Gravelly Hill, Birmingham, Eng. Feb. 23, 1906

BESSEY, CARL ATHEARN, Draughtsman, 437 North Central Ave., Austin, Chicago, Ill. May 19, 1903

BESSEY, EDWARD ATHEARN, Engineer, General Electric Co., Great Barrington, Mass. July 28, 1903

BETHELL, FRANK HOPKINS, General Manager, Chesapeake & Potomac Tel. Co., 722 12th St. N. W., Washington, D. C. Mar. 27, 1903

BETHELL, U. N., 1st Vice-president, The New York Telephone Co., 15 Dey St., New York City. Jan. 17, 1894

BETTS, HOBART D., *E.E.*, Room 1520, 299 Broadway; res., 264 W. 57th St., New York City. Aug. 5, 1896

BEUGLER, HUGH M., Dodge & Day, Drexel Building, Philadelphia, Pa. Jan. 23, 1903

BEULÉ, ABEL, Chief Electrician, Jackson Electric Railway Light and Power Co.; res., 317 E. Capitol St., Jackson, Miss. Nov. 23, 1906

BEVAN, TOM WILLIAM, Rio de Janeiro Tramway Light and Power Co., Ltd., Avenida Central 76, Rio Janeiro, Brazil, S. A. Aug. 17, 1904

BEVENUE-MILLER, EDWIN DAVID, Electrical and Mechanical Assistant, Kilburn & Co., Cawnpur, India. Mar. 28, 1902

BEYER, HENRY, Sales Department, Crocker-Wheeler Co., 1315 North American Bldg., Philadelphia, Pa. Jan. 25, 1907

BIBBINS, JAMES ROWLAND, Westinghouse Machine Co., Pittsburg, Pa. Dec. 19, 1902

BICKEL, ACKERT, Manager, Hodge-Walsh, Electrical Engineering Co., 701 Delaware St., Kansas City, Mo. Mar. 25, 1904

BICKFORD, EDGAR F., Boston & Northern & Old Colony St. Railway Co., 84 State St., Boston, Mass. Mar. 23, 1906

BICKNELL, DANA EDWIN, Assistant in Inspection Dept., Western Electric Co., 57 Bethune St., New York City. June 28, 1901

BIDDLE, JAMES G., Electrical and Scientific Instruments. 1114 Chestnut St., Philadelphia; res., Wallingford, Pa. Aug. 5, 1896

BIDWELL, CARLYLE D., Sub-Foreman, Western Electric Co.; res., 2633 N. Hermitage Ave., Chicago, Ill. June 21, 1907

BIEBEL, HERMAN MATTHEWS, Designing Electrical Engineer, Western Electric Co., Hawthorn, Ill. Apr. 23, 1903

BIGLER, EDWARD GOTTLIEB, Draftsman, Western Electric Co.; res., 3251 Prairie Ave., Chicago, Ill. Mar. 1, 1907

BIGELOW, HORATIO, Consolidated Railway Co., Norwich, Conn. June 21, 1907

BIJUR, JOSEPH, *A.B.*, President and Manager General Storage Battery [Life Member.] Co , 42 Broadway, New York City. May 15, 1894

BILDHAUSER, HENRY JEROME, Electrical Engineer, General Electric Co., 44 Broad St., New York City. Nov. 20, 1903

BINDEMANN, HARRY OTTO FERDINAND, Chief Engineer, Rhinisch-Westfalian, Electricity Works, Essen-Ruhr, Germany. Jan. 24, 1902

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BINGAY, ROBERT V., Pittsburg Transformer Co., Pittsburg, Pa. Dec. 18, 1903

BINGHAM, ALBERT RAIGUEL, Operator, Hudson River Electric Power Co., Albany; res., Spier Falls, N. Y. June 21, 1907

BINNEY, HAROLD, Partner, Binney Breckenstein and Ogden, 2 Rector St.; res., 10 Lexington Ave., New York City. July 26, 1907

BIRCH, ARTHUR KNODE, Sales Department, Bullock Electric Mfg. Co., Cincinnati, Ohio. Feb. 27, 1903

BIRD, WILLIAM LISTER, Superintendent, Kaministiqua Power Co., Ft. William, Ont. Mar. 27, 1903

BISHOP, WARREN JOSEPH, Erecting Engineer, Allis-Chalmers Co.; res., 904 Summit Ave., Milwaukee, Wis. June 21, 1907

BISHOP, WILLIAM SMART, Engineering Apprentice, Bullock Electric Co.; res., 2315 Norwood Ave., Norwood, Ohio. Apr. 27, 1906

BISSELL, GEORGE WELTON, Dean of Engineering, Michigan Argricultural College, East Lansing, Mich. Apr. 23, 1903

BISSING, WILLIAM F., Electrical Engineer and Patent Attorney, Kenyon & Kenyon, 2 Rector St., New York City. Jan. 23, 1903

BIVINS, WALTER THOMAS, Engineer Electrical Equipment, United Railroads, San Francisco, Cal. June 21, 1907

BLACK, CHAS. N., Ford, Bacon & Davis, 24 Broad St.; res., 43 E. 57th St., New York City. Apr. 19, 1890

BLACK, HOWARD D., With Blackall & Baldwin, 39 Cortlandt St.; res., 340 Manhattan Ave., New York N. Y. Sept. 15, 1897

BLACK, NEWTON HENRY, Instructor, Physics and Chemistry, Roxbury Latin School, Boston; Mass. June 21, 1907

BLACK, ROBERT GIVEN, Electrical Engineer, Toronto Electric Light Co., Toronto, Ont. May 21, 1901

BLACK, ROY HARRY, 1457 Page St., San Francisco, Cal. July 28, 1903

BLACK, SAMUEL DUNCAN, Electrical Engineer, The Rowland Telegraphic Co., Baltimore. Mar. 27, 1903

BLACKALL, FREDERICK S., 39 Cortlandt St.; res., 51 Manhattan Ave., New York. Sep. 15, 1897

BLACKWELL, HENRY FIELD, Electrical Engineer, Dept. of Water Supply, Municipal Building, Brooklyn, N. Y. Sept. 25, 1903

BLACKWELL, HOWARD LANE, Assistant in Physics, Harvard University; res., 160 Brattle St., Cambridge, Mass. Jan. 24, 1902

BLACKWELL, RUSS F., General Manager, Coeur d' Alene & Spokane Railway Co., Coeur d'Alene, Idaho. Oct. 27, 1905

BLAKE, EDWIN MORTIMER, Professor of Mechanical Engineering, University of Arizona, Tucson, Ariz. Mar. 1, 1907

BLAKE, EDWIN TYLER, 2233 Piedmont Way, Berkeley, Cal. May 19, 1903

BLAKE, ELI JUDSON, Draftsman, Electrical Engineers' Office, N. Y. C. & H. R. R.R.; res., 57 N. 7th St., Newark N. J. Mar. 25, 1904

BLAKE, HENRY M., Superintendent, The Jenkintown Light Co., Wyncote, Pa. July 28, 1903

BLAKE, HENRY W., Editor, *Street Railway Journal*, 239 W.39th St., New York City. Nov. 13, 1888

BLAKE, S. HENRY, [*Local Secretary*] Engineer of Arc Lighting, Stanley G. I. Electric Mfg. Co., Pittsfield, Mass. April 23, 1903

BLAKE, THEODORE W., Electrical Engineer, Goodyear Insulating Co., 1955 Park Ave.; res., Engineers' Club, New York. Sept. 20. 1893

BLAKEMORE, MAURICE NEVILLE, Electrical Engineer, with Westinghouse E & M Co., Pittsburg; res., Wilkinsburg, Pa. Jan. 25, 1901

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BLAKENEY, HENRY GEISEN, Tester, Dallas Electric Light and Power Co., Dallas, Tex. June 21, 1907

BLAKESLEE, HENRY JONES, Superintendent, Bureau of Gas and Electricity, Room 111, Court House, Syracuse, N. Y. Aug. 22, 1902

BLALOCK, IRA ALLEN, Chief Electrician Florida East Coast Railway Co., St. Augustine, Fla. Dec. 28, 1906

BLANCHARD, CHARLES M., General Superintendent Black Band Coal & Coke Co., Chilton W. Va. Sep. 19, 1894

BLEO, WILLIAM ERICSON, Inspector Elec. Dept. Dist. of Columbia; res., 464 Louisiana Ave., Washington, D. C. Jan. 23, 1903

BLEYER, ARTHUR, Estimator, M. B. Foster Electric Co., 949 Broadway; res., 449 E. 57th St., New York City. May, 14 1906

BLISS, DONALD M., President and Engineer-in-chief, Engineering Specialty Co., 143 Liberty St., New York City. June 19, 1903

BLISS, LOUIS DENTON, Principal Bliss Electrical School, 219 G St., N. W., Washington, D. C. July 12, 1900

BLISS, WILLIAM L., *B.S.*, *M.M.E.*, President Bliss Electric Car Lighting Co., 136 Liberty St., New York City. Mar. 21, 1894

BLIZARD, CHARLES, 3d Vice-President Electric Storage Battery Co., 19th St. and Allegheny Ave., Philadelphia. Nov. 21, 1894

BLIZARD, JOHN WALTER FREDERICK, Chief Draughtsman, Keystone Telephone Co., Philadelphia, Pa. May 17, 1904

BLONCK, WILLIAM A., Consulting Electrical Engineer, 404 Fisher Bldg., Chicago Ill. Apr. 23, 1903

BLONDEL, ANDRE E., 41 Avenue de la Bourdonnais, Paris, France. May 15, 1905

BLOOD, GROSVENOR TARBELL, Electrical Engineer, American Telephone and Telegraph Co., 15 Dey St., New York City. Mar. 27,1903

BLOSSOM, FRANCIS, Sanderson & Porter, 52 William St., New York City. July 25, 1902

BOERI, ALBERT P., Engineering Dept., The N. Y. Telephone Co., 15 Dey St., New York City. Dec. 18, 1903

BOGEN, LOUIS E., Estimating Engineer, Bullock Electric Mfg. Co., Cincinnati, O. May 16, 1899

BOGUE, CHARLES J., Chas. J. Bogue Electric Co., 213 Center St., New York City. Dec. 3, 1889

BOLAN, THOMAS V., Engineer, General Electric Co., Witherspoon Bldg. res., 518 N. 40th St., Philadelphia, Pa. Aug. 5, 1899

BOLDENWECK, FELIX WILLIAM, Engineering Department, Western Electric Co.; res., 27 Stratford Pl., Chicago, Ill. Mar. 25, 1904

BOLDMAN. CURTIS F., Engineering Apprentice, Westinghouse Elec. and Mfg. Co., East Pittsburg, Pa. Jan. 25, 1907

BOLLES, FRANK G., International Specialties Co., 12 Gold St., New York City. May 21, 1901

BOLSER, MILES ORTON, Spokane, Wash. Apr. 26, 1907

BOND, ARTHUR B., Power Department, Syracuse Lighting Co., Syracuse, N. Y. Mar. 25, 1904

BONINE, CHARLES EDWARD, Rossmassler, Bonine Electric Co., 1236 Orkney St., Philadelphia, Pa. June 19, 1903

BONNARJEE, BASANTA CHANDRA, Electrical Engineer, Long Beach, Cal. Jan. 27, 1905

BONNEY, ROBERT BRIDGE, Colorado Telephone Co., 1421 Champa St., Denver, Colo. Mar. 27, 1903

BONYUN, MORGAN EVAN, Small Motor Specialist, General Electric Co., Atlanta, Ga. Mar. 25, 1904

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BOORSE, JESSE M., Engineer on Construction, Omaha Electric Light and Power Co.; res., 825 Park Ave., Omaha, Neb. Sep. 28, 1906

BOOTH, WILLIAM THOMAS, Electrical Engineer, Eng. Dept. Western Electric Co., 463 West St., New York City. June 19, 1903

BORGER, HENRY EDWIN, Electrical Engineer, Dayton Electrical Mfg. Co.; res., 70 Springfield St., Dayton, O. Mar. 1, 1907

BORIE, RENSHAW, Long Island R.R., Morris Park L. I., N. Y. Mar. 25 1904

BORTENLANGER, JOSEPH A., General Contractor, 1614 Farnam St., Omaha, Neb. June 19, 1903

BOURNE, CHARLES OSCAR, Electrician, U. S. Navy Yard, Boston; res., 218 Howard St., Melrose, Mass. July 19, 1904

BOUSTEAD, JAMES TIMOTHY, President, Electric Machinery Co.; res., Calhoun Boulevard, Minneapolis, Minn. Sep. 28, 1906

BOWDEN, ZOLLY MASBY, Mulberry, Fla. Sept. 25, 1903

BOWEN, ABRAM CLERKE, District Inspector, New York and New Jersey Telephone Co., 25 Market St., Morristown, N. J. July 26, 1907

BOWEN, BENJAMIN JAMES, Equipment Engineer, New England Telephone and Telegraph Co., 101 Milk St., Boston, Mass. Apr. 26, 1907

BOWEN, HARRY W., Patent Attorney, Chapin & Co., 310 Main St., Springfield, Mass. Mar. 1, 1907

BOWIE, AUGUSTUS JESSE, JR., Irrigation Engineer, U. S. Department of Agriculture, Washington, D. C. May 15, 1900

BOYCE, ERNEST WALTON, Student, Polytechnic Institute of Brooklyn; res., 552 Dean St., Brooklyn, N. Y. Jan. 26, 1906

BOYD, HUGH HARKNESS, Assistant Electrical Engineer, Canadian Pacific Railway Co., Winnipeg, Canada. Apr. 26, 1907

BOYD, VALENTINE, Power Plant Salesman, Canadian General Electric Co., Ltd.; res., 181 Bloor St. E., Toronto, Ont. Feb. 26, 1904

BOYDEN, CLARENCE GILBERT, Operator of Autographic Test Car, with A. B. Herrick, Ridgewood, N. J. Sep. 28, 1906

BOYDEN, JOHN HANSON, Electrical Patent Expert, Meyers, Cushman and Rea, 510 McGill Bldg., Washington, D. C. Jan. 25, 1907

BOYER, FRANK N., Manager Supply Department, General Electric Co.; Monadnock Building, Chicago, Ill. June 19, 1903

BOZARTH, HARVEY, Ft. Wayne Electric Co., 110 State St., Boston, Mass. Jan. 26, 1906

BRACKETT, BYRON B., Professor of Electrical Engineering, Clarkson School of Technology; Potsdam, N. Y. Nov. 30, 1897

BRACKETT, PROF. CYRUS F., Princeton, N. J. Apr. 15, 1889

BRADDELL, ALFRED E., Sprague Electric Co., 527 W. 34th St., New York City. Sept. 1, 1890

BRADFIELD, WILLIAM WALTER, Chief Electrical Engineer, Marconi Wireless Tel. Co., of Am., 27 William St., New York City. Mar. 27,1903

BRADFORD, WILLIAM, Superintendent of Manufacture, Lincoln Gas and Electric Light Co., Lincoln, Neb. June 21, 1907

BRADLEY, ALONZO B., Electrical Engineer, 41 Park Row, New York City. Aug. 22, 1902

BRADLEY, KENNETH MCCLURE, Foreman, Transformer Testing Department General Electric Co., Lynn, Mass. Apr. 23, 1903

BRADLEY, WILLIAM EARLE, Electrical Engineer, Howson and Howson 32 S. Broad St., Philadelphia, Pa. Mar. 23, 1906

BRADY, NICHOLAS F., Treasurer, The N. Y. Edison Co., 57 Duane St., New York City. May 21, 1901

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BRADY, PAUL T., Westinghouse Electric and Mfg. Co., 11 Pine St., N. Y. July 12, 1887

BRADY, WILLIAM BURKE, Electrical Engineer, Brown Hoisting Machinery Co., Cleveland, O. Mar. 25, 1904

BRAGA, EDUARDO, JR., Assistant Electrical Engineer, Lidgerwood Mfg. Co., Ltd., Sao Paulo, Brazil, S. A. Feb. 27, 1903

BRAGG, GEORGE HENRY, Pacific Gas & Electric Co., 925 Franklin St., San Francisco, Cal. Nov. 24, 1905

BRALLEY, WALTER SUVIER, Assistant Engineer, General Electric Co., Schenectady, N. Y. Nov. 23, 1906

BRAMHALL, CHARLES A., Manager, Diehl Mfg. Co., 561 Broadway, New York City; res., Allendale, N. J. May 17, 1904

BRANCH, BENJAMIN HARRISON, Virginia Passenger and Power Co., Richmond, Va. Nov. 23, 1906

BRANCH, GEORGE IRVING, Draughtsman, Electrical Department, N. Y. C. and H. R. R.R. Co.; New York City. Apr. 26, 1907

BRANDAO, BENJAMIN, Electrical Engineer, Empresa Forca e Luz de Pouso Alegre, Bello Horizonte, Brazil Sept. 28, 1906

BRANDAO, JULIO VIVEIROS, *C.E.*, Rua Barao do Flamengo 8, Rio de Janeiro, Brazil, S. A. Jan. 25, 1901

BRANDENBURGER, LEO, Telluride Power Co., Provo, Utah. Oct. 27, 1905

BRANDT, ALBERT UPP, Inspector, California Gas and Electric Corp., 272 62d St., Oakland, Cal. May 15, 1905

BRATNEY, JOHN FREDERICK, Engineer, Bell Telephone Co., of Mo., Telephone Building, St. Louis, Mo. Dec. 18, 1903

BRAUN, CHRISTIAN EDWARD, Draughtsman, Western Electric Co., New York City; res., 33 Hinckley Ave., Brooklyn, N. Y. Sept. 27, 1901

BRAY, CHARLES AYERS, Electrical Engineer, 702 Gay St., Knoxville, Tenn. May 19, 1903

BRAYSHAW, J., Telegraph Superintendent Great Southern Railway, City of Buenos Aires, A. R. Aug. 5, 1896

BRECK, CHESNEY YALES, Westinghouse Electric and Mfg. Co., Denver, Colo. July 28, 1903

BREED, EVERETT MARK, District Manager, Allis-Chalmers-Bullock Co., Ltd., Vancouver, B. C. Apr. 26, 1907

BREED, GEORGE, Consulting Engineer, 931 Real Estate Trust Building; res., 406 W. Price St., Germantown, Philadelphia, Pa. Jan. 29, 1904

BREESE, CHARLES PARKER, Breese & Mitchell, Atlantic Trust Bldg., Norfolk, Va. Mar. 27, 1903

BRESSAN, ANTHONY, Electrician, Helios Manufacturing Co., Bridesburg, Pa. Mar. 24, 1905

BRETT, JAMES A., Westinghouse Electric & Mfg. Co., 1104 Traction Building, Cincinnati, Ohio. Apr. 23, 1903

BREWSTER, WALTER SCOTT, Electrician, Standard Underground Cable Co.; res., 65 Kearney Ave., Perth Amboy, N. J. Apr. 26, 1901

BRIDGE, JAMES WELDON, United Coal Co., 901 Bank for Savings Building, Pittsburg, Pa. Jan. 27, 1905

BRIDGMAN, GREENVILLE TEMPLE, 264 Newbury St., Boston, Mass. Dec. 18, 1903

BRIESEN, HAROLD V., Engineering Department, American Telephone and Telegraph Co., 22 Thames St., New York City. June 28, 1901

BRIGGS, WALLACE WHEATON, District Office Manager, Westinghouse E. & M. Co., 2d and Howard Sts., San Francisco, Cal. Feb. 23, 1906

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BRIGGS, ZENAS MARSTON, Railway Engineering Department, General Electric Co., Schenectady, N. Y. Jan. 25, 1907

BRIGHT, GRAHAM, Engineer, 705 Pitts St., Wilkinsburg, Pa. May 19, 1902

BRIGHT, HERBERT LOOSE, Inspector and Draftsman, New York Central and Hudson River Railroad, New York City. June 21, 1907

BRIGHTMAN, CARL GORDON, Supt. Lines and Bonding, Old Colony Street Railway Co.; res., 31 White St., Taunton, Mass. Apr. 23, 1903

BRISCOE, EDWARD ANDREW, Engineering Department, Telluride Power Co., Telluride, Colorado. Jan. 27, 1905

BRISCOE, HERBERT WITHINGTON, Salesman, Ft. Wayne Electric Works, 325 Lincoln Trust Bldg., St. Louis, Mo. Mar. 29, 1907

BRISLEY, EDWARD BETTS, V. P. and Treasurer, Standard Engineering Corp., 1121 Land Title Bldg. Philadelphia, Pa. Apr. 25, 1902

BRITTON, JOHN ALEXANDER, General Manager, California Gas and Electric Corporation, 925 Franklin St., San Francisco, Cal. July 28, 1905

BRIXEY, W. R., Proprietor and Manufacturer, Day's Kerite Wire and Cables, 203 Broadway, New York City. Sept. 20, 1893

BROADHURST, WM. CHANNING, Electrical Engineer, 320 Greene Ave., Brooklyn, N. Y. Aug. 22, 1902

BROCKWAY, EDWIN L., General Feeder Foreman N. Y. C. Ry. Co.; res., 1020 Simpson St., New York City. Jan. 25, 1907

BROICH, JOSEPH, Superintendent and Electrician with F. Pearce, 18 Rose St., New York; res., 1622 8th Ave., Brooklyn, N. Y. Jan. 17, 1894

BROOKE, IRVING EMERSON, Draftsman, John A. Radford, 1325 Marquette Building, Chicago, Ill. Sept. 25, 1903

BROOKE, ROBERT THOMAS, JR., Supply Department, Florida Electric Co., Jacksonville, Fla. Apr. 23, 1903

BROOKS, FRANK HARRISON, Lincoln Traction Co., Lincoln, Neb. Feb. 27, 1903

BROOKS, GEORGE WAINWRIGHT, Toledo and Chicago Interurban Ry. Co., Kendallville, Ind. May 14, 1906

BROOKS, LOUIS C., Master Electricians C. & R. Dept., Navy Yard, Boston, Mass. Aug. 22, 1902

BROOME, GEORGE WILEY, Electrician, General Electric Co.; res., 832 Union St., Schenectady, N. Y. June 14, 1905

BROPHY, WILLIAM, Consulting Electrical Engineer, 17 Egleston St., Jamaica Plain, Mass. Mar. 5, 1889

BROSIUS, FRANK R., Columbus Railway and Light Co., 410 King Ave., Columbus, O. Oct. 28, 1904

BROSIUS, JAMES SIMMS, Electric Controller and Supply Co., Cleveland, Ohio. May 17, 1904

BROUGHTON, HAROLD HODGKINSON, Electrical Engineering Department, Technical College, Brighton, England. Sept. 28, 1906

BROUGHTON, HENRY PRIMM, General Manager, Great Northern Power Co., Providence Bldg., Duluth, Minn. Aug. 25, 1905

BROUGHTON, JAMES RUSSELL, Telluride Power Co., Ames, Col. Apr. 23, 1903

BROWD, PAUL K., Engineer, 10 line Ligovka 13, St. Petersburg, Russia. Feb. 15, 1899

BROWN, ALFRED EVELYN, Partner, Scott and Brown, Christchurch, New Zealand. May 17, 1904

BROWN, ARTHUR JAMES, Draughtsman, Bullock Electric Mfg. Co., Cincinnati, Ohio. Mar. 27, 1903

BROWN, ARTHUR NOBLE, Westinghouse Electric & Mfg. Co., New York Life Building, Chicago, Ill. Mar. 27, 1903

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BROWN, CARLTON EMERSON, 2317 N. Avers Ave. Chicago, Ill. Mar. 27, 1903

BROWN, CHARLES L., Sales Engineer, Allis-Chalmers Co., Milwaukee, Wis. Nov. 20, 1895

BROWN, CLARENCE CLAPP, Assistant Engineer, Bell Telephone Co., 11th and Filbert Sts., Philadelphia, Pa. June 21, 1907

BROWN, DICKSON QUEEN, Director, Tidewater Oil Co., 11 Broadway res., 160 W. 59th St., New York City. May 19, 1903

BROWN, EDWARD CLAUDE, Inspector, Electric Department, N. Y. C. & H. R. R. R.; res., 206 E. 58th St., New York City. Dec. 28, 1906

BROWN, ELLIS EUGENE, Manager, Brown Engineering Co., Second National Bank Bldg. Reading, Pa. May 16, 1899

BROWN, FREDERICK DILL, Twin City Rapid Transit Co.; res., 3711 Nicollet Ave., Minneapolis, Minn. Jan. 25, 1907

BROWN, GARRY ESTEP, Edison Electric Ill. Co., of Brooklyn, 360 Pearl St.; res., 1284 Dean St., Brooklyn, N. Y. Sept. 25,1903

BROWN, GEORGE WILLIAM, Master Mechanic, Lexington Railway Co., Lexington, Ky. Mar. 29, 1907

BROWN, HAROLD SLATER, Agent, Canadian General Electric Co., 14 King St., E., Toronto, Ont. Mar. 29, 1907

BROWN, HARRY ARTHUR, Assistant Development Engineer, Central District and Printing Telegraph Co., Pittsburg, Pa. Dec. 28, 1906

BROWN, HARVEY LANGDON, Erecting Engineer, Stanley Electric Mfg. Co.; res., 81 Appleton Ave., Pittsfield, Mass. Mar. 24, 1905

BROWN, HUGH AUCHINCLOSS, Electrical Engineer, Crocker-Wheeler Co., Old Colony Building, Chicago, Ill. Mar. 28, 1902

BROWN, HUGH THOMAS, Engineer, Stone & Webster Engineering Corporation, 84 State St., Boston, Mass. Jan. 26, 1902

BROWN, JOHN ELLIOTT, Electrical Engineer, Consumers' Electric Co.; res., 53 Waverly St., Ottawa, Can. Mar. 27, 1903

BROWN, JOHN ROWLAND, Chief Engineer, Mansfield Works, Stirling Consolidated Boiler Co., Mansfield, O. Jan. 26, 1906

BROWN, JAMES HALLY, General Electric Co., Schenectady, N. Y. Sept. 22, 1905

BROWN, JAMES WILBERT, Superintendent Transportation, West Penn. Railway Co., Connellsville, Pa. Apr. 28, 1905

BROWN, PERCY M., Operator, Huronian Co., Turbine, Ont. June 21, 1907

BROWN, ROBERT CALTHROP, Consulting Engineer, Toronto Ry. Co.; res., St. George Apartments, Toronto, Ont. June 19, 1903

BROWN, ROY WILCOX, Manager, Globe Electric Controller Co., 299 Guy Park Ave., Amsterdam, N. Y. Dec. 15, 1905

BROWN, SYDNEY WILLIAM, Construction Engineer, Canadian Westinghouse Co., Sovereign Bank Building, Montreal, Que. May 19, 1903

BROWN, WALTER EVERETTE, Engineer N. Y. & N. J. Telephone Co., res., 1178 Degraw St., Brooklyn, N. Y. May 20, 1902

BROWN, WALTER SCOTT, Manager, Supply Dept., Kilbourne & Clark Co.; res. 113 Marion St., Seattle, Wash. Nov. 24, 1905

BROWN, WALTER THROOP KENDALL, Power and Lighting Engineer, Stanley G. I. Elec. Mfg. Co., Pittsfield, Mass. Jan. 25, 1907

BROWN, WARREN DAY, 79 Park Ave., New York City. Jan. 25, 1901

BROWN, WILFRED JAMES, Repair Electrician, Shawinigan Water and Power Co., Shawinigan, Falls, Can. Apr. 26, 1907

BROWNE, ROBERT LEWIS, Experimenting, Cooper Hewitt, Electric Co.; res., 219 W. 83d St., New York City. Dec. 28, 1906

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BROWNE, WILLIAM HAND, JR., Technical Editor, *Electrical Review*, 1000 Park Row Building, New York City. Apr. 25, 1903

BROWNE, WILLIAM HENRY, 86 South 10th St., Brooklyn, N. Y. May 20, 1902

BROWNELL, FRANK WILBUR, Hudson River Telephone Co., Goshen, N. Y. Apr. 26, 1907

BROWNELL, WILLIAM HENRY, York Haven Water and Power Co.; York Haven, Pa. Dec. 15, 1905

BRUCH, CHARLES PATTERSON, Assistant General Manager, Postal Telegraph Cable Co., 253 Broadway, New York City. Mar. 25, 1904

BRUNDIGE, JOHN ALVIN, Assistant, Niagara Construction Co., Ltd., Niagara Falls, N. Y. July 19, 1904

BRUNDRETT, ERNEST LOW, General Auditor, United Gas Improvement Co., Philadelphia; res., Haverford, Pa. Jan. 27, 1905

BRUNSKOG, VICTOR, Engineer, Jeffrey Mfg. Co.; res., 310 W. 9th Ave.; Columbus, O. Feb. 26, 1904

BRUSH, FREDERICK FARNSWORTH, Engineer, 1331 Penobscot Building, Detroit, Mich. Feb. 28, 1901

BRYANT, ARTHUR HORACE, Tester, Electrical Testing Laboratories, 80th St. and East End Ave., New York City. Apr. 22, 1904

BRYANT, FRED L., Consulting Engineer, Spartanburg, S. C. May 15, 1905

BRYANT, JOHN MYRON, Instructor in Electrical Engineering, University of Illinois, Urbana, Ill. Feb. 26, 1904

BRYANT, WALDO CALVIN, Manager, The Bryant Electrical Co., Bridgeport, Conn. May 19, 1903

BUCHANAN, CHARLES C., Switchboard Inspector, General Electric Co.; res., 935 State St., Schenectady, N. Y. Sept. 28, 1906

BUCHANAN, JOHN LEE, Electrical Engineer, General Electric Co., Schenectady, N. Y. Dec. 28, 1906

BUCHANAN, JAMES ROBERT, Assistant Engineer, General Electric Co., Witherspoon Bldg., Philadelphia, Pa. Jan. 26, 1906

BUCK, ALFRED H., Wire Chief, New York Telephone Co., 114 W. 89th St., New York City. July 26, 1907

BUCK, A. MORRIS, JR., Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. June 14, 1905

BUCK, HENRY CHASE, Instructor Electrical Engineering American School of Correspondence, Chicago, Ill. Mar. 1, 1907

BUCK, MARION ESTES, Superintendent, Generating Plant, The Power Co., Norris, Mont. Jan. 23, 1903

BUCKE, WILLIAM AUGUSTUS, Agent Canadian General Electric Co., 14 King St., East Toronto, Ont. Dec. 19, 1902

BUCKINGHAM, CHARLES L., Attorney and Counsellor-at-Law, Potter Building, 38 Park Row, New York City. Apr. 15, 1884

BUCKNER, BEN FORSYTHE, Assistant Superintendent Overhead Lines, Allegheny County Light Co., Pittsburg, Pa. Mar. 1, 1907

BUDDY, HARRY JOHN, General Selling Agent, General Electric Co., Witherspoon Bldg., Philadelphia, Pa. June 19, 1903

BUECHNER, CARL AUGUST, Student, Polytechnic Institute of Brooklyn; res., 225 83d St., Brooklyn, N. Y. Dec. 28, 1906

BULKELEY, CLAUDE AUGUSTUS, Board of Education, St. Louis, Mo. Sept. 28, 1906

BULL, ROBERT WILSON, Supt., Tri-Bullion, Smelting & Development Co., Canton City, Col. Mar. 22, 1901

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BULLARD, ALBERT MORRISON, Engineering Dept., Western Electric Co. 463 West St., New York City. Mar. 27, 1903

BULLEN, DANA RIPLEY, General Electric Co., Schenectady, N. Y. Mar. 28, 1902

BULLOCK, FRANK E., District Inspector, Chesapeake and Potomac Telephone Co.; res., 929 N. Broadway, Baltimore, Md. June 21, 1907

BULLOCK, GEORGE, President, Bullock Electric Mfg. Co., 71 Broadway, New York City. Feb. 27, 1903

BUMP, MILAN RAY, With H. L. Doherty, 60 Wall St., New York City. Mar. 27, 1903

BUMPASS, WALTER LEONARD, Electrician, Duncan Light and Power Co., Duncan, I. T. Sept. 28, 1906

BUNCE, THEODORE D., President, The Storage Battery Supply Co., 239 E. 27th St., New York City. May 20, 1890

BUNJE, CHARLES, JR., Draughtsman, Public Service Corporation; res., 14 Webster Ave., Jersey City, N. J. Aug. 17, 1904

BUNKER, ARTHUR CLIFFORD, 42 Myrtle Ave., Montclair, N. J. Oct. 25, 1901

BURCHENAL, CHARLES DAY, Electrical Engineer, Honolulu Iron Works Co., 11 Broadway, New York City. July 28, 1905

BURK, ADDISON BROWN, JR., Asst., Construction Engineer, Electric Storage Battery Co., 1400 Association Bldg., Chicago, Ill. Mar. 1, 1907

BURKETT, CHAS. WATSON, Chief Engineer, Wisconsin Telephone Co., Milwaukee, Wis. Aug. 23, 1899

BURKHOLDER, CHARLES IRVINE, Manager Operating Dept., Southern Power Co., Charlotte, N. C. Apr. 23, 1903

BURNETT, JAMES AUBREY, Engineering Dept., Montreal Light, Heat and Power Co., N. Y. Life Building, Montreal, P. Q. Apr. 26, 1902

BURNHAM, GEORGE A., Electrical Engineer, Tufts College, Mass. Dec. 18, 1903

BURNHAM, JOSEPH LLOYD, Designing Engineer, General Electric Co.; res., 29 Chestnut St., Schenectady, N. Y. Dec. 28, 1906

BURNS, DAWSON JABEZ, General Sales Manager, Ward Leonard Electric Co., res., 602 W. 146th St., New York City. Jan. 29, 1904

BURNS, HARVEY LYNN, Telephone Engineer, Western Electric Co., 463 West St.; res., 10 W. 64th St., New York City. June 21, 1907

BURNS, OMEN C., Electrical Operator, I. R. T. Co., 74th St. and East River, New York City. Mar. 27, 1903

BURNS, WILLIAM GIBSON, Electrical Engineer, with Jabez Burns & Sons, 542 Greenwich St., New York City. May 19, 1903

BURR, FRANK DANIEL, 1924 N. Tijon St., Colorado Springs, Col. Mar. 1, 1907

BURRITT, ALEXANDER HAMILTON, 6 Mt. Vernon St., Cliftondale, Mass. Apr. 23, 1903

BURROWS, WILLIAM RUSSELL, Experimenter General Electric Co., Harrison; res., 666 Ridge St., Newark, N. J. Mar. 27, 1903

BURSON, HERBERT ARTHUR, Chief Engineer, Packard Electric Co., St. Catharines, Ont. Sept. 26, 1902

BURT, AUSTIN, General Superintendent, Citizens' Gas and Electric Co., Waterloo, Iowa. June 21, 1907

BURTON, CHARLES GILLETTE, Manager, Peru Electric Mfg. Co., Peru, Ind. Feb. 28, 1902

BURTON, FRANK VAIL, Bryant Electric Co., 142 State St.; res., 157 Coleman St., Bridgeport, Conn. Mar. 28, 1902

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BURTON, PAUL G., Division Supt. Chesapeake & Potomac Telephone Co., 722, 12th St., Washington, D. C. Nov. 20, 1895

BUSH, ARTHUR RICHMOND, General Electric Co., Boston; res., 1479 Beacon St., Brookline, Mass. Apr. 23, 1903

BUSH, GEORGE TICKIOB, Engineering Dept., Southern Bell Tel. and Tel. Co., Atlanta, Ga. Oct. 26, 1906

BUSH, HENRY F., JR., Erecting Engineer, Westinghouse Electric and Mfg. Co.; res., 2011 Market St., Philadelphia, Pa. June 21, 1907

BUSHNELL, S. MORGAN, Engineer, Chicago Edison Co., 139 Adams St.; res., Hyde Park Hotel, Chicago, Ill. Feb. 27, 1903

BUSHNELL, WINTHROP GRANT, President, Connecticut Power Co., New Haven, Conn. Mar. 27, 1903

BUST, FREDERICK HODGETTS, Student, General Electric Co.; res. 185 No. Common St., Lynn, Mass. Jan. 26, 1906

BUTLER, HENRY WEIL, Engineer, Manhattan Railway Co.; res., 56 E. 50th St., New York City. Jan. 23, 1903

BUTLER, WILLIAM, Electrical Engineer, Lockport Gas and Electric Light Co., 107 Grand St., Lockport, N. Y. Apr. 26, 1907

BUTLER, WILLIAM C., President, The Puget Sound Reduction Co., Everett, Washington. Mar. 21, 1893

BUTLER, WILLIAM WILSON SAMUEL, General Manager and Engineer, N. N. & O. P. Ry., & Elec. Co., Hampton, Va. Feb. 26, 1904

BUTTERWORTH, ISAAC NELSON, General Manager, Tri-City Electric Co.; res., 405 Brady St., Davenport, Iowa. May, 19, 1903

BUTTS, D. JAY, Engineer Salesman, Western Electric Co.; res., 235 West 128th St., New York City. Mar. 1, 1907

BUXTON, RAYMOND ELMER, Supply Department, General Electric Co., Schenectady, N. Y. Dec. 28, 1906

BUYS, ALBERT, Electrical Engineer, Ovid Electric Co., Ovid, N. Y. Feb. 7, 1890

BYERS, VERNON CLYDE, Assistant in Engineering Department, J. G. White and Co., 43 Exchange Place, New York City. Apr. 26, 1907

BYINGTON, ALBERT JACKSON, Consulting Engineer and Contractor, Byington & Co., Sao Paulo, Brazil, S. A. Oct. 23, 1903

BYLLESBY, HENRY MARISON, President, H. M. Byllesby and Co., New York Life Building, Chicago, Ill. May 17, 1904

BYRNES, EUGENE A., *Ph. D.*, Byrnes & Townsend Patent Lawyers, 1918 F. St., N. W., Washington, D. C. May 21, 1901

BYRNS, ROBERT A., Electrical Engineer, 120 Liberty St., New York City. Dec. 16, 1896

CABOT, FRANCIS ELLIOTT, Assistant Secy. and Electrician, Boston Board of Fire Underwriters, 55 Kilby St., Boston, Mass. Apr. 17, 1895

CADBY, JOHN NELSON, Professor of Electrical Engineering, University of New Mexico, Albuquerque, N. M. Mar. 1, 1907

CADE, HOWARD EDWARD, Assistant Inspector, Navy Department, U. S. Government, Pencoyd, Pa. Jan. 26, 1906

CADY, LAWRENCE WHITTREDGE, Chief Engineer, W. J. Barr Electric Mfg. Co., 1936 E. 59th St., Cleveland, Ohio. Apr. 23, 1903

CAHILL, THADDEUS, Cabot Street Mill, Holyoke, Mass. Sept. 28, 1906

CALDERWOOD, HUGH ALEXANDER, Electrical Inspector, Underwriters' Association of the Middle Dept., Pittsburg, Pa. July 28, 1903

CALDWELL, EDWARD, Importer and Dealer, Technical Books and Periodicals, 239 W. 39th St., New York City. Jan. 20, 1891

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CALDWELL, EUGENE WILSON, Electrical Engineer, 36 W. 35th St.; res., 20 E. 31st St., New York City. Jan. 24, 1902

CALISCH, JULIUS C., Manager Buffalo Office, General Electric Co., Ellicott Square Building, Buffalo, N. Y. Dec. 19, 1902

CALVERT, RICHARD C. M., Assistant Chief Electrical Engineers to Govt. Mysore, Bangalore, India. Sept. 25, 1903

CAMERON, GAYLOR MALCOLM, Draftsman, Cleveland Electric Railway, 9902 Lamont Ave., N. E. Cleveland, Ohio. Nov. 23, 1906

CAMERON, HENRY FRANCIS, Acting Representative, Westinghouse E. M. Co., 1110 Hibernia Bank Bldg., New Orleans, La. Sept. 22, 1905

CAMPBELL, GEORGE ASHLEY, Electrical Engineer, The American Telephone and Tel. Co., 15 Dey St., New York City. Mar. 27, 1903

CAMPBELL, GORDON MCKAY, Assistant Superintendent, Western Electric Co., Hawthorn, Ill. Apr. 27, 1906

CAMPBELL, HENRY ARTHUR, Electrician, West India Electric Co., Ltd., 151 Orange St., Kingston, Jamaica, W. I. Sept. 27, 1899

CAMPBELL, JOHN, President and General Manager, Electrical Auditing Co., 727 Old South Bldg., Boston, Mass. Feb. 26, 1904

CAMPBELL, JOHN M., General Manager, Buffalo, Lockport and Rochester Railway, Kingston, Ont. Apr. 26, 1907

CAMPBELL, JOSEPH WILLIAM, Canadian General Electric Co., Ltd., 14 King St., E.; res., 92 Glen Road, Toronto, Ont. July 28, 1903

CAMPBELL, WILSON LEE, Assistant Superintendent, Automatic Electric Co.; 35 So. Spring Ave., La Grange, Ill. Sept. 22, 1905

CANADA, WILLIAM JOSEPH, Electrical Inspector, Electrical Inspection Bureau, Conover Bldg., Dayton, O. Mar. 25, 1904

CANDEE, WILLARD L., Manager, Okonite Co., Ltd., 253 Broadway, New York City; res., 293 Garfield Pl., Brooklyn, N. Y. Mar. 25, 1904

CANFIELD, CHARLES ERNEST, Electrical Engineer, Western Electric Co.; res., 197 Lexington St., Chicago, Ill. Aug. 22, 1902

CANFIELD, MILTON C., Electrical Engineer, 1508 Kenilworth Ave., Ohio. Feb. 21, 1893

CANNON, E. F., 309 McKay Bldg., Portland, Ore. May 15, 1905

CANNON, ROSCOE SHERWOOD, Superintendent, Catawba Power Co., Rock Hill, S. C. Sept. 28, 1906

CAPEN, BERNARD W., Equipment Engineer, Nebraska Telephone Co., Omaha, Neb. May 14, 1906

CARD, JOHN FRANCIS, Designing Engineer and Supt. Three Rivers Electric Co., Three Rivers, Mich. Aug. 17, 1904

CARGO, LAWRENCE M., Manager, Westinghouse Electric and Mfg. Co., 429 17th St.; res., 2714 E. 13th St., Denver, Colo. May 14, 1906

CARIAPA, CODANDA M., Bangalore, India. July 19, 1904

CARLE, NATHANIEL ALLEN, Engineer, Westinghouse, Church, Kerr & Co., 606 Mercantile Bldg., Denver, Colo. Dec. 28, 1906

CARLE, RAY ARTHUR, Erecting Engineer, Westinghouse Electric and Mfg. Co., 1502 Continental Trust Bldg., Baltimore, Md. Apr. 26, 1907

CARLEBACH, WALTER MAXWELL, Student, Columbia University; res., 136 W. 86th St., New York City. June 19, 1903

CARLIN, WILLIAM HENRY, Electrical Engineer, H. Eckstein & Co., Johannesburg, S. A. Sept. 25, 1903

CARLTON, WILLARD GILBERT, Superintendent Power, Pt. Morris, Power Station, 142d St. and East River, New York City. Oct. 25, 1901

CARMAN, CHARLES WHITNEY, Partner, Charles Whitney Carman & Co., 657 Railway Exchange, Chicago, Ill. June 15, 1904

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CARMAN, WARREN RAYMOND, Superintendent, D. H. Burnham & Co., 13 Astor Place, New York City. Nov. 23, 1906

CARNAGHAN, E. D., *M. E.*, Ventanas Consolidated Mining and Milling Co., Villa Corona, Do. Mexico. July 26, 1900

CARPENTER, CHAS. E., Cutler-Hammer Mfg. Co., 136 Liberty St., New York City. Aug. 5, 1896

CARPENTER, EUGENE, Newton, Mass. Oct. 28, 1904

CARPENTER, HENRY CANNON, Assistant in Engineering Department N. Y. Telephone Co.; res., 113 E. 69th St., New York City. Oct. 25, 1901

CARPENTER, HOWARD DOTTY, [*Local Secretary*] University of Missouri, Columbia, Mo. Mar. 24, 1905

CARPENTER, HUBERT VENTON, Professor of Mechanical Engineering, Washington Agricultural College, Pullman, Wash. Feb. 27, 1903

CARPENTER, LEONARD, Electrical Engineer, Curtis & Hine, Giddings Bldg., Colorado Springs, Colo. Mar. 1, 1907

CARR, ALFRED EDWARD, Electrical Engineer, Power House, Formby, near Liverpool, Eng. July 28, 1903

CARR, JOHN HERBERT, Chief Electrician, Arnold Print Works, North Adams, Mass. Dec. 18, 1903

CARROLL, LOUIS WARDEN, Telephone Engineer, Western Electric Co., Chicago; res., Riverside, Ill. Apr. 26, 1907

CARROLL, MORRIS B., Construction Department, General Electric Co., Schenectady, N. Y. June 15, 1904

CARTER, CHARLES EDWARD, Superintendent of Distribution, Madison Gas and Electric Co., Madison, Wis. June 21, 1907

CARTER, FREDERICK WILLIAM, *M.A.*, British Thomson-Houston Co., Ltd., Rugby, Eng. Sept. 28, 1898

CARTER, GEORGE WILLIAM, Engineering Department, Stanley G. I. Electric Mfg. Co., Pittsfield, Mass. Mar. 29, 1907

CARTER, HENRY HARCOURT, 185 Schermerhorn St., Brooklyn, N. Y. Nov. 25, 1904

CARTER, WILSON ANDRUS, Electrical Engineer, Denver Gas and Electric Co., 405 17th St., Denver, Colo. June 21, 1907

CARTWRIGHT, CRELLIN, Engineer, General Electric Co. 23 Water St., Yokohama, Japan. Dec. 18, 1903

CARY, EDWARD EGBERT, President and Treasurer, Edward E. Cary Co., 59 Park Place, New York City. June 21, 1907

CARY, WALTER, General Manager, Westinghouse Lamp Co., 510 W. 23d St. res., 16 E. 31st St., New York City. Jan. 25, 1907

CASE, HERBERT MONROE, Commercial Engineer, General Electric Co., Cincinnati, O. Nov. 24, 1905

CASE, WILLARD E., 196 West Genesee St., Auburn, N. Y. Feb. 7, 1888

CASSEL, ISAAC MICHAEL, General Electric Co., Citizens Building, Cleveland, Ohio. Feb. 23, 1906

CASSIDY, JOHN, Electrical Engineer and Contractor, 159 South King St., Honolulu, Hawaiian Islands, U.S.A. Nov. 23, 1898

CASTLE, ARTHUR COWLES, District Engineer, W. E. & Mfg. Co 403 Second National Bank Building, Pittsburg, Pa. Sept. 28, 1906

CATCHINGS, F. P., Electrical Engineer, North Georgia Electric Co., 1222 Candler Building, Atlanta, Ga. Aug. 25, 1905

CAUCHOIS, REGINALD WADSWORTH, Student, Columbia University; res., 458 W. 144th St., New York City. Apr. 26, 1907

CAVE, ERNEST L., Resident Engineer, Kolar Gold Fields, Electricity Department, Oorgaum, Mysore State, S. India. Apr. 27, 1906

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CECIL, THOMAS, Chief Electrician, *New York Herald*, Broadway and 35th St.; res., 514 W. 134th St., New York City. Apr. 23, 1903

CHACE, WILLIAM GREGORY, Electrical Engineer, Room 124, Confederation Life Building, Toronto, Ont. Oct. 23, 1903

CHALMERS, CHARLES HENRY, Vice-president and General Manager, Electric Machinery Co., Minneapolis, Minn. Feb. 27, 1903

CHAMBERLAIN, AARON FRANKLIN, Westinghouse Electric and Mfg. Co.; 1104 Traction Bldg., Cincinnati, O. Dec. 19, 1902

CHAMBERLAIN, FREDERICK ARTHUR, Electrical Engineer, American Gas & Electric Co., Witherspoon Bldg., Philadelphia, Pa. June 21, 1907

CHAMBERLAIN, RUFUS N., Superintendent, Gould Storage Battery Co., Depew, N. Y. Mar. 25, 1904

CHAPIN, CHARLES H. B., Contract and Inspection Dept., New York Edison Co., 30 W. 32d St., New York City. Oct. 27, 1905

CHAPMAN, ALBERT PERCY, Student, Worcester Polytechnic Institute; res., 45 Institute Road, Worcester, Mass. Sept. 28, 1906

CHAPMAN, A. WRIGHT, Turner Construction Co., Room 301, 11 Broadway, New York City. Mar. 25, 1896

CHAPMAN, CHARLES ARTHUR, Consulting Engineer, 1041 Marquette Bldg., Chicago, Ill. Mar. 24, 1905

CHAPMAN, FREDERICK STORRS, 123 So. Negley Ave., Pittsburg, Pa. Apr. 27, 1906

CHAPPELL, WALTER E., Engineer, British Westinghouse Electric & Mfg [Life Member.] Co., Ltd., Trafford Park, Manchester, Eng. May 16, 1899

CHAPPELOW, FAY ELDON, Chappelow & Goe Adv. Co., June 21, 1907

CHARTERS, SAMUEL BARCLAY, Instructor, Leland Stanford Junior University, Palo Alto, Cal. Jan. 26, 1906

CHASE, BURDETTE LEONARD, Superintendent of Line Construction, Columbus Railway and Light Co., Columbus, O. Feb. 26, 1904

CHASE, CHARLES ALBERT, Engineer, Mexican General Electric Co., Mexico City, Mex. Apr. 23, 1903

CHASE, MELVILLE B., Westinghouse Electric & Mfg. Co., 131 State St., Boston; res., 491 Western Ave., Lynn, Mass. May 15, 1905

CHATFIELD, CLARENCE EDWARD, Student, Cornell University; res., 614 E. State St., Ithaca, N. Y. Sept. 28, 1906

CHEEVER, MARKHAM, Telluride Power Co., Provo, Utah. Sept. 25, 1903

CHEEVER, PAUL, Niagara Falls, N. Y. Jan. 27, 1905

CHELLIS, GEORGE FREDERICK, Erecting Engineer, J. G. White & Co., 49 Exchange Place, New York City. Mar. 24, 1905

CHENEY, EDWARD J., Assistant Foreman, Testing Department, General Electric Co., Schenectady, N. Y. Nov. 23, 1906

CHESTER, M. E., Telephone Engineer, Western Electric Co., 463 West St.; res., 296 Manhattan Ave., New York City. Feb. 28, 1902

CHESTERMAN, FRANCIS JOHN, Engineering Department, New York Telephone Co., 15 Dey St., New York City. Jan. 25, 1907

CHETWOOD, ROBERT EDES, JR., Assistant Electrician, The American Teleph. and Tel. Co., 22 Thames St., New York City. Mar. 27, 1903

CHILD, ROLAND SPEAKMAN, Instructor, Brooklyn Polytechnic Institute; res., 22 Garden Place, Brooklyn, N. Y. Apr. 26, 1907

CHILDS, JOSEPH SAMUEL, Electrician, 596 William St., Buffalo, N. Y. Mar. 25, 1904

CHILDS, SUMNER W., Construction Engineer, J. G. White & Co., Rock Island, Ill. May 15, 1894

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CHINN, ORAL MURAT, Electrician, Mt. Vernon Electric Light and Railway Co., Hotel Fultz, Mt. Vernon, O. Mar. 24, 1905

CHISHOLM, FREDERICK JOHN, Electrical Engineer, 83 Herry St., Brooklyn, N. Y. May 19, 1903

CHUBB, WILLIAM MASON, Assistant Electrical Engineer, Signal Corps, U. S. A., 263 Summer St., Boston, Mass. Nov. 24, 1905

CHUBBUCK, LEONARD BURROWS, Engineering Department, Westinghouse E. & Mfg. Co.; res., 510 South Ave., Pittsburg, Pa. Feb. 28, 1902

CHURCHILL, CLARENCE EVERETT, Superintendent, Meter Service, Condor Water Power Co., Medford, Oregon. Sept. 28, 1906

CHURCHWARD, ALEXANDER, Electrical Engineer, General Electric Co., 44 Broad St., New York City. Mar. 27, 1903

CHURCHWARD, ERNEST CALERIDGE, General Manager, Scottish Central Elec. P. Co., 34 N. Bridge St., Edinburgh, Scotland. Mar. 29, 1907

CHRISTENSEN, CHRISTIAN H., Missoula Light and Water Co., 740 Monroe St., Missoula, Mont. June 21, 1907

CLACK, CHARLES WILLIAM, Telephone Engineer, Western Electric Co., N. Woolwich; res., Finsbury Park, London, Eng. May 19, 1903

CLAFLIN, GEORGE EDWIN, Electrical Engineer, United Electric Securities Co., 47 Ames Bldg., Boston, Mass. May 15, 1905

CLAREMONT, ERNEST ALEXANDER, Managing Director, W. T. Glover and Co., Ltd.; Manchester, England. Oct. 26, 1906

CLARK, CHAS. M., *E.E.*, Clark & MacMullen, 22 Broad St., New York City. Apr. 22, 1896

CLARK, CLARENCE DOANE, Engineering Department, California Gas & Elec. Co., Napa, Cal. May 19, 1903

CLARK, FARLEY GRANGER, Superintendent Power Station, Penn., N. Y. & L. I. R.R. Co., Long Island City, N. Y. Apr. 26, 1901

CLARK, NORMAN FREDERIC, Electrical Engineer, Wm. E. Baker & Co., 27 William St.; res., 120 W. 116th St., New York City. Jan. 23, 1903

CLARK, ROBERT J., Assistant to Comptroller, Toronto Railway Co.; res., 104 Avenue Road, Toronto, Ont. Mar. 29, 1907

CLARK, THOMAS E., Electrical Engineer, 193 Cass Ave., Detroit, Mich. Feb. 26, 1904

CLARK, TRUE S., Partner, Bates and Clark Co., 508 Pacific Block, Seattle, Wash. Apr. 27, 1906

CLARK, WALLACE S., Engineer, Wire, Cable and Tube Department, General Electric Co., Schenectady, N. Y. Apr. 25, 1902

CLARK, WALTER G., President, Parker Clark, Electric Co., 135 Broadway, New York City. Mar. 27, 1903

CLARK, WM. EDWIN, Clark & Mills, Engineers and Contractors, 543 Boylston St., Boston, Mass. Aug. 23, 1899

CLARK, WILLIAM J., General Manager, Foreign Dept., General Electric Co., 44 Broad St., New York City. Apr. 22, 1896

CLARK, WINFRED NEWCOMBE, Superintendent, Pueblo & Suburban Traction & Lighting Co., Victor, Colo. Mar. 24, 1905

CLARKE, HENRY PHILIP, Master Mechanic, New York City Railway Co., res., 133 W. 140th St., New York City. June 21, 1907

CLARKE, HERBERT ALMYR, Consulting Engineer, 6 William St., Auburn N. Y. Nov. 25, 1904

CLARKE, LEON, Electrical Engineer, National Brake & Electric Co., Milwaukee, Wis. July 28, 1903

CLARKE, WILLIAM A., Cashier, Toledo Gas Electric and Heating Co.; res., 1638 Broadway, Toledo, O. Mar. 1, 1907

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CLARKE, WILLIAM B., Manager, General Electric Co., 1518 Park Bldg., Pittsburg, Pa. Jan. 25, 1907

CLARY, CLAUDE L., General Manager, Sikeston Ice, Light and Power Co., Sikeston, Mo. May 15, 1905

CLAY, JOHN ALLEN, Electrical Engineer, Animas Power & Water Co., Silverton, Col. Oct. 28, 1904

CLAYTON, B. WILLIAM, Engineer, General Electric Co.; res., 631 Western Ave., West Lynn, Mass. Mar. 29, 1907

CLELAND, HARRY W., 1012 Wood St., Wilkinsburg, Pa. Dec. 18, 1903

CLEMENT, EDWARD E., Patent Attorney and Electrical Expert, McGill Building, 908 G. St., N. W., Washington, D. C. May 18, 1897

CLEMENT, HENRY CHAMBERLAIN, Assistant Engineering Department, J. G. White & Co., New York City. Apr. 26, 1907

CLEMENT, STEPHEN ROBERT ADDISON, Testing Department General Electric Co., Schenectady, N. Y. Apr. 27, 1906

CLIFF, RICHARD CHARLES, Consulting Electrical Engineer, Liverpool & London, Chambers, 62 Pitt St., Sydney, N. S. W. Sept. 25, 1903

CLIFT, ARTHUR S., Chief Mechanical Engineer, Siemens Bros. & Co., Ltd., Woolwich, Kent, Eng. Sept. 27, 1901

CLIFT, ROBERT LEE, Traveling Salesman, Electric Supply Co., Memphis, Tenn. Apr. 27, 1906

CLINGERMAN, BYRON HORACE, Electrical Engineer, Cor. Main & Limestone Sts., Springfield, Ohio. May 15, 1905

CLORAN, GERALD JOSEPH, Electrical Engineer, 320 St. Nicholas Ave., New York City. June 19, 1903

CLOUGH, ALBERT L., Manchester, N. H. Feb. 21, 1894

CLOUGH, FREDERICK HORTON, Alternating Current Designing Office, British-Thomson-Houston Co., Rugby, Eng. June 19, 1903

COATES, CHARLES BENJ., Electrical Engineer, Chicago Pneumatic Tool Co., 1010 Fisher Bldg., Chicago, Ill. Jan. 23, 1903

COBLE, FREDERICK H., Assistant to Superintendent of Power & Construction, with L. B. Stillwell, Baltimore, Md. May 15, 1905

COCHRAN, BERRY WYNN, Engineering Department, Southern Bell Telephone Co., 92 Pulliam St., Atlanta, Ga. June 19, 1903

COCHRANE, HARRY HAMILTON, Engineer, Butte Electric & Power Co., Butte, Mont. Nov. 25, 1904

COCKEY, EDMUND AUGUSTUS, JR., Construction Man, Westinghouse Electric & Mfg. Co., Baltimore, Md. Oct. 27, 1905

CODMAN, JOHN STURGIS, Consulting Engineer, 220 Devonshire St.; res., 57 Marlborough St., Boston, Mass. Feb. 15, 1899

CODY, L. P., Manager and Engineer, Grand Rapids Electric Co., 9 South Division St., Grand Rapids, Mich. Aug. 5, 1896

COE, ELMER RANSOM, Assistant to Electrical Engineer, Union Switch and Signal Co., Swissvale, Pa. Mar. 1, 1907

COEY, STEWART CLARK, Assistant in Electrical Department, J. G. White & Co., 43 Exchange Place, New York City. Apr. 26, 1907

COFFIN, CHAS. A., General Electric Co., 44 Broad St., New York City. Dec. 6, 1887

COFFIN, FRANCIS PARKMAN, Engineer, Research Laboratory, General Electric Co. res., 223 Union St., Schenectady, N.Y. Mar. 23, 1906

COFFIN, STANLEY D., Western Electric Co., 259 S. Clinton St., Chicago, res., Riverside, Ill. Mar. 24, 1905

COFFMAN, CHARLES HENRY, Electrical Engineer, National Telephone and Electric Co., Clinton, Ill. Sept. 28, 1906

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COGAN, HENRY MANNING, Electrical Engineer, The American Sugar Refining Co., Kent Ave., Brooklyn, N. Y. Sept. 26, 1902

COGGESHALL, ALLAN, N. Y. & N. J. Telephone Co., 547 Clinton Ave., Brooklyn, N. Y. Jan. 27, 1905

COGGESHALL, ROBERT FARRINGTON, General Electric Co.; res., 18 Rugby Road, Schenectady, N. Y. Dec. 28, 1906

COGGIN, WILLIAM LORD, Tester General Electric Co.; res., 10 Arlington St., Lynn, Mass. Apr. 22, 1904

COGHLIN, JOHN P., Electrical Engineer and Contractor, Page Electric Co., 24 Pearl St., Worcester, Mass. Sept. 27, 1901

COHEN, DOUGLAS HART, Engineering Draughtsman, Westinghouse, Church, Kerr & Co., New York City. Jan. 25, 1907

COHEN, LOUIS, Librarian, Bureau of Standards, Washington, D. C. Jan. 25, 1907

COHO, HERBERT B., Sales Manager, Burke Electric Co., 26 Cortlandt St., New York City; res., Mt. Vernon, N. Y. Mar. 21, 1894

COKEFAIR, CHARLES COIT, President, Great Northern Development Co., Duluth, Minn. Oct. 26, 1906

COKEFAIR, FRANCIS ALBERTON, Chief Engineer, Great Northern Power Co., Duluth, Minn. Sept. 25, 1903

COLBY, SAFFORD KINKEAD, Treasurer Pierson Roeding & Co., 77 New Montgomery St., San Francisco, Cal. May 19, 1903

COLDWELL, ORIN B., Operating Superintendent and Electrical Engineer, Portland General Electric Co., Portland, Ore. Mar. 27, 1903

COLE, ARTHUR WILLIAMS, Instructor, Mechanical Engineering, Purdue University; res., 523 Russell St., W. Lafayette, Ind. Nov. 23, 1906

COLE, GEORGE MARSHALL, Engineer, Plattsburg Light, Heat & Power Co., Plattsburg, N. Y. July 25, 1902

COLE, GEORGE PERCY, Engineering Dept., Allis-Chalmers-Bullock Co., Ltd., Montreal, Que. Oct. 23, 1903

COLE, HENRY ERNEST, Electrical Engineer, 1023 Park Building, Pittsburg, Pa. July 28, 1903

COLE, JAMES E., Chief Electrician, Wire Department, City of Boston, 11 Wareham St.; res., 64 Perham St., Boston, Mass. July 26, 1907

COLE, JAMES LEVERN, Assistant Foreman, Westinghouse Electric and Mfg. Co., Newark, N. J. Dec. 28, 1906

COLEMAN, EDWARD J., Superintendent, N. Y. City Interborough Railway Co.; res., 2004 Washington Ave., New York City. Apr. 26, 1907

COLEMAN, S. WALDO, 1834 California St., San Francisco, Cal. June 15, 1904

COLES, EDMUND P., Engineer, Scofield Co., Philadelphia, Pa. Oct. 23, 1895

COLES, HENRY A., Salesman, Westinghouse Electric and Mfg. Co., 623 Empire Building, Atlanta, Ga. Mar. 25, 1904

COLES, WILLIAM CRUSE, Supply Salesman, General Electric Co., Atlanta, Ga. Mar. 1, 1907

COLGAN, JAMES ARTHUR HERBERT, Electrical Engineer, Western Electric Co., 463 West St., New York City. Jan. 25, 1907

COLKET, JAMES HAMILTON, Engineer, N. Y. & N. J. Telephone Co.; res., 288 DeKalb Ave., Brooklyn, N. Y. Apr. 27, 1906

COLLETT, CHARLES OTTO, Instructor, Electrical Engineering, University of Missouri; res., 708 Maryland Place, Columbia, Mo. Mar. 29 1907

COLLETT, SAMUEL D., Eastern Manager, Elevator Supply and Repair Co., 136 Liberty St., New York City. Feb. 26, 1896

COLLIER, WILLIAM RAWSON, [*Local Secretary*], Contract Agent, Georgia Railway and Electric Co., Atlanta, Ga. May 19, 1903

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COLLINS, CURTIS C., Electrical Engineer, Columbus Railway & Lt. Co., Columbus, Ohio. Oct. 24, 1902

COLLINS, EDGAR FRANCIS, Foreman, Testing Department, General Electric Co., Schenectady, N. Y. June 15, 1904

COLLINS, FRED LUKE, Assistant Chief Electrician, Illinois Steel Works; res., 746 E. 70th St., Chicago, Ill. Feb. 23, 1906

COLLINS, HENRY P., General Superintendent, Herkimer County Light and Power Co., Little Falls, N. Y. Jan. 26, 1906

COLLYER, ALFRED, District Manager, Bullock Electric Mfg. Co., 402 Merchants' Bank Building, Montreal, Can. Aug. 22, 1902

COMSTOCK, CHARLES WORTHINGTON, Consulting Engineer, Engineering Co. of America, 213 Boston Building, Denver, Colo. June 19, 1903

CONDIT, BENSON CLARE, Supt. American River Electric Co., Trucker River G. E. Co., San Mateo, Cal. July 19, 1904

CONDIT, CLYDE ERNEST, Goldfield Electric Light and Power Co., Goldfield, Nevada. July 19, 1904

CONKLING, DEWITT C., Inventor and Model Maker; res., 1215 Washington St., Hoboken, N. J. Sept. 25, 1903

CONKLIN, OLIVER FRANCIS, Consulting Electrical Engineer, The Robbins & Myers Co., Springfield, Ohio. Oct. 25, 1901

CONLEE, FREDERICK MONROE, Chief Draftsman, Northern Electric Mfg Co.; res. 1212 Spraight St., Madison, Wis. Dec. 18, 1903

CONN, FRANK, W., Superintendent, N. Y. & N. J. Tel. Co., 81 Willoughby St.; res., 77 St. James Pl., Brooklyn, N. Y. July 28, 1903

CONNELL, HARRY WESTCOTT, Consulting Engineer, Connell Sykes & Connell, 90 West St., New York City. May 15, 1905

CONNELL, HARVEY FRANCIS, Engineer, 90 West St., New York City. Feb. 23, 1906

CONNELLY, WILLIAM FREDERICK, Electrician, Camp Bird Mill, Ouray, Colorado. Nov. 23, 1906

CONRAD, FRANK, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg; res., Swissvale, Pa. Dec. 19, 1902

CONRAD, NICHOLAS JOHN, Electrical Engineer, Testing Department, Chicago Edison Co., 139 Adams St., Chicago, Ill. Apr. 26, 1907

CONVERSE, V. G., Electrical Engineer, Ontario Power Co., Niagara Falls South, Ont. Nov. 23, 1900

CONWELL, WALTER LEWIS, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City; res., Upper Montclair, N. J. May 20, 1902

COOK, ARTHUR LEROY, Engineer, Westinghouse Church, Kerr & Co., 10 Bridge St., New York City. Dec. 19, 1902

COOK, HARRY LAWRENCE Inspector of Lighting Department, Columbus Railway and Light Co., Columbus, O. Feb. 26, 1904

COOK, James Carr, Constructing Engineer, Jos. B. McCrary, Geneva, Ala. June 19, 1903

COOKE, JOHN WILLIAMSON, Operating Department Engineer, Electric Storage Battery Co., 60 State St., Boston, Mass. Feb. 26, 1904

COOLIDGE, FREDERICK AUSTIN, Electrical Review, 21 Park Row, New York City. Sept. 28, 1906

COOPER, DRURY W., Member of Firm, Kerr, Page and Cooper, 149 Broadway, New York City; res., New Brunswick, N. J. June 21, 1907

COOPER, EDGAR BAILEY, Ponce Railway and Light Co., Ponce, P. R. Oct. 27, 1905

COOPER, JOHN SISSON ST. GEORGE, Electrical Engineer British Westinghouse E. and M. Co., Trafford Park, Manchester, Eng. Apr. 28, 1905

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COOPER, LEO HENRY, Switchboard Installer, Tri-State Telegraph and Telephone Co., Minneapolis, Minn. Apr. 26, 1907

COOPER, WILLIAM RANSOM, Consulting Engineer, with James Swinburne, 82 Victoria St., London, Eng. July 25, 1902

COPE, ALBERT NATHAN, Electrical Engineer, Columbus Public Service Co.; res., 191 N. 21st St., Columbus, O. Apr. 22, 1904

COPELAND, CLEM A., Consulting Engineer, 407 Citizens Bank Building, Los Angeles, Cal. June 23, 1897

COPLEY, ALMON WARREN, Engineer, 213 Lucas Building, Mt. Vernon, N. Y. Jan. 29, 1904

CORA, CHARLES ANTHONY, Central Union Tel. Co., 35 West Ohio St., Indianapolis, Ind. Dec. 19, 1902

CORBETT, LAURENCE JAY, Electrical Engineer, 501 Empire State Building, Spokane, Washington. Mar. 27, 1903

CORDELL, WILLIAM H., General Foreman, New York Edison Co.; res., 548 W. 156th St., New York City. Jan. 25, 1907

CORIN, WILLIAM, City Electrical Engineer, 7 Hill St., Launceston, Tasmania. Sept. 28, 1906

CORLISS, CYRUS, Engineer, Boston Elevated Railway Co., Boston; res., 695 Walk Hill St., Mattapan, Mass. April 27, 1906

CORNELL, JOHN B., Niles-Bement-Pond Co., 111 Broadway, New York City. Sept. 25, 1895

CORNICK, TULLY R., Superintendent Transmission Lines, Mexican Light and Power Co., Mexico City, Mex. Jan. 25, 1907

CORNING, JOHN WOODSIDE, Electrical Engineer, Boston Elevated Ry. Co.; 439 Albany St., Boston; res., Brookline, Mass. Jan. 23, 1903

CORNMAN, GEORGE W. W. JR., Supt. Keystone Elec. Inst. Co., 9th & Montgomery Ave., Philadelphia, Pa. Jan. 23, 1903

CORNWALL, CLEMENT ARTHUR, Engineer in charge of shift, B. C. Electric Railway Co., Vancouver; res., Ashcroft, B. C. May 19, 1903

CORRIGAN, EDWARD, Superintendent, Chesapeake and Potomac Telephone Co., 5 Light St., Baltimore, Md. June 21, 1907

CORSON, WILLIAM R. C., Assistant Engineer, Hartford Steam Boiler Inspection Insurance Co., Hartford, Conn. Jan. 17, 1893

CORY, RUSSELL GADUS, Electrical Engineer, with C. O. Mailloux, 76 William St., New York City. Oct. 26, 1906

COSEO, GEORGE EDWARD, Chief Electrician, Solvay Process Co.; res., 123 Erie St., Syracuse, N. Y. Oct. 28, 1904

COSTA, LOUIS J., Manager, Jandus Electric Co., 1229 Real Estate Building; res., 5010 Newhall St., Philadelphia, Pa. Apr. 22, 1904

COULTER, Leonard PORTER, Electrical Engineer, Cutler-Hammer Mfg. Co.; res., 342 W. 24th St., Milwaukee, Wis. Apr. 28, 1905

COVENTRY, WILLIAM HENRY, Electrical Engineer, International Paper Co., Palmer, N. Y. Mar. 24, 1905

COWEN, JULIAN BETTY, General Storage Battery Co., 42 Broadway, New York City. Feb. 28, 1902

COWGILL, JOHN SHEPHERD, Electrical Engineer, Three Rivers Electric Works, Three Rivers, Mich. Dec. 23, 1904

COWLE, GERALD ARTHUR, Power & Mining Dept., General Electric Co., Schenectady, N. Y. Mar. 25, 1904

COWLEY, THOMAS PHILIP, Electrical Engineer, Chicago Telephone Co., 203 Washington St., Chicago, Ill. Sept. 28, 1906

COWLING, JOHN T., Electrical Engineer, Westchester Lighting Co., Mt. Vernon, N. Y. Nov. 25, 1904

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COWPER, COLES-SHERARD OSBORN, Grosvenor Mansions, 82 Victoria St., London, S. W., Eng. Aug. 22, 1902

COX, CHARLES GORDON, Testing Department, General Electric Co.; res., 115 Park Ave., Schenectady, N. Y. Jan. 27, 1905

COX, DAVID CHAMBERS, 90 West St., New York City. Sept. 28, 1906

CRABB, CHARLES LOUIS, C. L. Crabb & Co., 21 Lincoln Place, Brooklyn, N. Y. Nov. 20, 1903

CRAFT, WARREN MOORE, Telephone Engineer, American Telephone and Telegraph Co., 15 Dey St., New York City. Mar. 29, 1907

CRAIG, FREDERICK T., United States Packing Co., Uruapan, Mex. Mar. 1, 1907

CRAIN, GEORGE HENRY, Marine Engine and Machine Co., 230 W. 13th St., New York City. Mar. 23, 1906

CRAIN, JOHN JAY, Quincy, Mass. Dec. 16, 1896

CRAIN, L. D., Assoc. Prof. Mech. Eng., The State Agriculture College, Fort Collins, Colo. Jan. 23, 1903

CRAMER, LEROY B., Engineering Department, Westinghouse Electric and Mfg. Co., 1107 Traction Building, Cincinnati, Ohio. July 28, 1905

CRAMER, STUART WARREN, Charlotte, N. C. Oct. 26, 1906

CRAMPTON, STEWART HOOKER, First Asst. Supervising Eng., N. Y. Teleph. Co., 614 E. 150th St., New York City. Jan. 23, 1903

CRANDALL, HERBERT NILES, Superintendent Fremont Power Co., Sumpter, Ore. Mar. 29, 1907

CRANE, ALBERT SEARS, Engineer, J. G. White & Co., 43 Exchange Pl. New York City. Oct. 28, 1904

CRANE, CHARLES EUGENE, President and Manager, Mutual Light and Heat Co., Seattle, Wash. Apr. 22, 1904

CRANE, EDGAR WILLIS, General Manager, Segura Brariff y Cia, Orizaba, Vera Cruz, Mexico. June 21, 1907

CRANE, HAROLD GILLILAND, Student, Massachusetts Institute of Technology, Boston, Mass. June 14, 1905

CRANE, HENRY MIDDLEBROOKE, 96 W. 7th St., Bayonne, N. J.; res., 532 Fifth Ave., New York City. Mar. 27, 1903

CRANE, JOS. BAIRD, Electrical Engineer, Newport Electric Lighting & Power Co., Newport, N. Y. Sept. 28, 1906

CRAVATH, JAMES RALEY, Western Editor, *Electrical World*, 500 Old Colony Building. Chicago, Ill. Nov. 23, 1901

CRAVENS, GEORGE WAVERLEY, Engineer, General Electric Co., Schenectady, N. Y. Apr. 26, 1907

CRAWFORD, DAVID FRANCIS, General Supt. Motive Power, Penn'a Co., Union Station, Pittsburg, Pa. Sept. 25, 1895

CRAWFORD, JACK RANDALL, 17 Stratton St., W. London, Eng. Dec. 19, 1902

CRAWFORD, MAGNUS TATE, Draftsman, Seattle-Tacoma Power Co., 911 Terrace St., Seattle, Wash. Apr. 26, 1907

CRAWFORD, NORMAN McDONALD, Consulting Engineer, 742 Connecticut Mutual Building, Hartford, Conn. Mar. 27, 1903

CRAWLEY, MANSFIELD CALVIN, Electrician, Union Oil Co. of California, Orcutt, Cal. Mar. 29, 1907

CREAGH, EDRIC COLLINGWOOD, Transformer Dept., British Westinghouse E. & M. Co., Trafford Park, Manchester, England. Oct. 27, 1905

CREAGHEAD, THOMAS J., President and General Manager, Creaghead Engineering Co., 313 Walnut St., Cincinnati, Ohio. Sept 20, 1893

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CREAGMILE, WILLIAM B., Instructor in Electrical Engineering, School of Engineering, Drexel Institute, Philadelphia, Pa. Mar. 1, 1907

CRECELIUS, LAWRENCE P., Superintendent of Power, Lee de Forest City Ry. Co., Cleveland, Ohio. Feb. 23, 1906

CREELMAN, ADAM, Superintendent, Rockland Electric Co., Hillburn, N. Y. Mar. 27, 1903

CREHORE, ALBERT C., *Ph.D.*, The Crehore-Squier Intelligence Transmission Co., Lincoln Terrace, Yonkers, N. Y. Dec. 21, 1892

CREIGHTON, ELMER ELLSWORTH FARMER, Assistant Prof. in Electrical Engineering, Union University, Schenectady, N. Y. May 20, 1902

CRESSY, LOUIS AGASSIZ, Shop Electrician, Electric Vehicle Co., Hartford, Conn. Aug. 17, 1904

CROCKER, JAMES ROGER, 215 W. 100th St., New York City. Dec. 19, 1902

CROCKER, OLIVER P., Fire Alarm Salesman, Gamewall Fire Alarm Co., 623 Equitable Bldg., Atlanta, Ga. Oct. 27, 1905

CROFT, TERRELL WILLIAMS, Special Inspector, N. Y. & N. J. Tel. Co., 547 Clinton Ave., Brooklyn, N. Y. Jan. 29, 1904

CROSBY, ROBERT H., Foreman, Interborough Rapid Transit Co.; res., 463 W. 164th St.; New York City. May 14, 1906

CROSS, ALBERT HENRY, General Superintendent, Manhattan Fire Alarm Co.; res., 51 Manhattan Ave., New York City. Feb. 23, 1906

CROSS, EDMUND RUST, Dynamo Testing, Department Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Feb. 27, 1903

CROSS, THOMAS A., Superintendent, United Railways and Electric Co., 1005 Continental Trust Co., Baltimore, Md. Mar. 24, 1905

CROSSE, SHIRLEY ROBBINS, Assistant in Electrical Engineering, Harvard University; res., 25 Ware St., Cambridge, Mass. Dec. 28, 1906

CROSSMAN, GILBERT, Telephone Engineer, Western Electric Co., 463 West St.; res., 145 W. 10th St., New York City. Nov. 22, 1901

CROUSE, JOHN ROBERT, Promoter, Co-operative Electrical Development Association, 1814 45th St., N. E. Cleveland, O. Sept. 28, 1906

CROWELL, HOWARD HORTON, Manager, General Electric Co., 602 S. A. and K. Bldg., Syracuse, N. Y. Sept. 22, 1905

CROWELL, LUTHER ALBERT O., Salesman, Westinghouse Electric and Mfg. Co., 716 Board of Trade Bldg., Boston, Mass. Apr. 26, 1907

CROWELL, ROBINSON, Transmission Dept., California Gas & E. Corp., Electra, Cal. Dec. 28, 1898

CROZIER, HERBERT WILLIAM, Central California Traction Co., Stockton, Cal. Apr. 23, 1903

CRUMB, WILLIAM HANFORD, President, W. H. Crumb & Co., Inc., 835 Monadnock Bldg., Chicago, Ill. Mar. 1, 1907

CRUMPTON, WILLIAM JAIRUS, 1111 Maple Ave., Superior, Wis. Sept. 25, 1903

CRUSE, GEORGE EDWIN, Patent Attorney, Union Switch and Signal Co., 143 Liberty St., New York City. Mar. 1, 1907

CULLEN, EDWARD L., 9 Woodland St., Worcester, Mass. July 28, 1903

CUMMISKEY, WILLIAM MICHAEL, Electrician, National Elevator Co.; res., 1517 West St., Honesdale, Pa. Apr. 23, 1903

CUNNINGHAM, E. R., Des Moines City Railway Co., 607 Mulberry St., Des Moines, Iowa. Jan. 22, 1896

CUNNINGHAM, JAMES H., Instructor Electrical Engineering, Union College; Schenectady, N. Y. Nov. 23, 1906

CUNNINGHAM, RICHARD H., Instructor in Electro-Physiology, Columbia University; res., 201 W. 54th St., New York City. May 21, 1901

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CUNTZ, JOHANNES H., *Engineering Magazine*, 140 Nassau St., New York City; res., 325 Hudson St., Hoboken, N. J. Mar. 5, 1889

CURRENT, GUY LEROY, Deskman, New York and New Jersey Telephone Co., 547 Clinton Ave., Brooklyn, N. Y. June 21, 1907

CURRIE, HARRY ALLAN, Electrician, N. Y. C. & H. R. R. R. Co.; res. 474 Bedford Ave., Brooklyn, N. Y. Apr. 23, 1903

CURRIE, N. M., Electrical Engineer, Electric Light Department, Cia de Gas de Valparaiso, Valparaiso, Chili. Feb. 15, 1899

CURRIE, WILLIAM JR., Electrical Engineer, 89 Union Ave., Montreal, Que. July 25, 1902

CURTIS, JOHN DANIEL Assistant Superintendent, Hatzel and Buehler; res., 552 W. 186th St., New York City. Feb. 23, 1906

CURTIS, KENNETH LIVERMORE, Engineer, Wesinghouse Church, Kerr & Co., 10 Bridge St., New York City. Oct. 27, 1905

CURTIS, LEONARD E., Vice-president and Treasurer, Guanajuato Power and Electric Co., Colorado Springs, Colo. May 17, 1904

CURTISS, JOHN LEE, Engineer, Juniata Hydro-Electric Co., 405 Penn St., Huntingdon, Pa. Feb. 23, 1906

CUSHING, HARVEY MORSE, Electrical Engineer, General Electric Co., 44 Broad St., New York City. Mar. 23, 1906

CUSHING, IRA MAY, Designing Electrical Engineer, General Electric Co.; Boston; res., 19 Harris St., Brookline, Mass. June 14, 1905

CUTCHEON, FREDERICK RICHARD, Superintendent Electric Dept., St. Paul Gas Light Co., St. Paul, Minn. Dec. 15, 1905

CUTLER, ELIHU HERBERT, Manager, The Elketon Mfg. Co., 84 Westminster St., Springfield, Mass. Apr. 23, 1903

CUTLER, HENRY H., Vice-president and Chief Engineer, The Cutler-Hammer Mfg. Co., Milwaukee, Wis. June 19, 1903

CUTLER, JAMES ELMER, Westfield, N. J. Apr. 25, 1902

CUTTER, FRED BERTRAM, Electrical Engineer, Rossiter, MacGovern & Co., 90 West St., New York City. July 28, 1905

CUTTING, FREDERICK STEWART, Electrical Construction Engineer, Massie Wireless Telegraph Co., Warren, R. I. Mar. 1, 1907

DAGGETT, ROYAL BRADFORD, Electrical Engineer, Electric Storage Battery Co., 525 Thirteenth St., Oakland, Cal. Jan. 25, 1899

DAHLANDER, ROBERT, Electrical Engineer, The Royal Government of the Railways of Sweden, Stockholm, Sweden. May 19, 1903

DALLAS, ROBERT E., United Gas Improvement Co., Broad and Arch Sts., Philadelphia, Pa. Sept. 28, 1906

DALTON, NELSON WAIT, Electrical Engineer, Hartford Carpet Corporation Thompsonville, Conn. June 15, 1904

DALY, WILFRID AUGUSTIN, Hudson Terrace, Yonkers, N. Y. Nov. 25, 1904

DAMON, GEO. A., Managing Engineer, The Arnold Co., Borland Building, 181 LaSalle St., Chicago, Ill. June 24, 1898

DAMON, JOHN CHURCHILL, 432 Main St., Concord, Mass. July 28, 1905

DANFORTH, JOHN BUCHANAN, Carter & Gillespie Electric Co., Birmingham, Ala. June 14, 1905

DANIELS, HAROLD PLATT, Engineer, Peet, McAnerney & Powers, 225 Fourth Ave., New York City. Dec. 19, 1902

DANIELS, NATHAN H., JR., Stone and Webster, 84 State St., Boston, Mass. Apr. 26, 1907

DANIELS, THOMAS EDWARD, JR., Chief Electrician, High Creek Electric Light and Power Co., Logan, Utah. Sept. 28, 1906

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DANIELS, RAYMOND SAFFORD, Electrical Construction Foreman, Washington Water Power Co., Spokane. Jan. 25, 1907

DANIELSON, ERNST, Electrician, Stopsjon, Fogdhyttan, Sweden. June, 27 1895

DANIELSON, OSCAR ALVIN, Engineer, Western Electric Co., 463 West St., res., 54 W. 65th St., New York City. Jan. 25, 1907

DANN, WALTER MELVILLE, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Aug. 17, 1904

DANNER, JAKE, Western Electric Co., Chicago; res., 1236 Euclid Ave., Oak Park, Ill. June 21, 1907

DARBEE, WILLIAM, General Manager, Albany & Hudson R.R., Albany, N. Y. Feb. 23, 1906

DARBY, HENRY FRANCIS, JR., Cutter Co., 1613 Chemical Building St. Louis Mo. Jan. 26, 1906

DARBY, WALTER RAINES, Pittsburg Reduction Co., 99 John St., New York City; res., 18 Summit Ave., Westfield, N. J. May 20, 1902

DARRACH, BRADFORD, JR., Construction Engineer, Electric Storage Battery Co., 39 Stanhope St., Boston, Mass. Feb. 26, 1904

DASSORI, FREDERICK HUMBERT, N. Y. & N. J. Telephone Co., 15 Dey St. New York City. May 21, 1901

DATES, HENRY B., Professor of Electrical Engineering, Case School of Applied Science, Cleveland, O. Dec. 28, 1898

DAVENPORT, ALFRED LA RUE, Tester, Edison Electric Co., of Los Angeles; res., 2903 Leoti Ave., Los Angeles, Cal Apr. 22, 1904

DAVENPORT, JOHN COOLIDGE, Electrical Engineer, Bullock Electric Mfg. Co., Cincinnati, O. Jan. 25, 1907

DAVENPORT, URIAH HARROLD, Adjunct Professor, University of Georgia, Athens, Ga. Mar. 29, 1907

DAVIDSON, EDW. C., Patent Lawyer, 141 Broadway, New York City. Feb. 7, 1890

DAVIDSON, JOHN CHALMER, P. N. Y. & L. I. R.R., 10 Bridge St., New York; res., 31 Sidney Place, Brooklyn, N. Y. Mar. 29, 1907

DAVIDSON, JOHN CLARENCE, Electrician and Chief Engineer, S. S. White Dental Mfg. Co., Princebay, N. Y. May 19, 1903

DAVIDSON, ROBERT NEWMAN, Superintendent, Park City Light, Heat and Power Co., Park City, Utah. Sept. 28, 1906

DAVIDSON, ROLLAND ARTHUR, 58 William St., New York City. Mar. 27, 1903

DAVIES, JOHN HUBERT, Senior Partner, Hubert Davies & Spain, Johannesburg, S. A. Oct. 23, 1903

DAVIS, ARTHUR PERCY, Walpole, N. H. July 28, 1903

DAVIS, CHARLES BRIDGE, Local Manager of Boston Office, General Electric Co., 84 State St., Boston; res., Lexington, Mass. Apr. 23, 1903

DAVIS, CHARLES STAPLES, Holtzer-Cabot Electric Co,. Brookline, Mass. Feb. 26, 1904

DAVIS, CHARLES WOOLSEY, Westinghouse Electric & Mfg. Co., Wilson Building, Dallas, Texas. Oct. 28, 1904

DAVIS, DELAMORE L., Superintendent, Salem Electric Light and Power Co., 299 Lincoln Ave., Salem, Ohio. Apr. 2, 1889

DAVIS, FRED HORNE, Consulting Engineer, Winchester House, Loveday St., Johannesburg, Transvaal. Sept. 25, 1903

DAVIS, FREDERICK REYNOLDS, Advertising Department General Electric Co.; res., 1208 State St., Schenectady, N. Y. Dec. 28, 1906

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DAVIS, G. SANFORD, Construction Engineer, Canadian General Electric Co., 14 King St., E., Toronto, Ont. Mar. 25, 1904

DAVIS, HOWARD LEE, Assistant in Engineering Department, N. Y. & N. J. Tel. Co., 15 Dey St., New York City. May 14, 1906

DAVIS, ERNEST, Draftsman, Sargent & Lundy; res., 405 North Central Ave., Chicago, Ill. Mar. 29, 1907

DAVIS, JESSE HOOD, Assistant Electrical Engineer, Baltimore & Ohio R.R. Co., B. & O. Building, Baltimore, Md. June 19, 1903

DAVIS, JOE MATHIAS, Electrician, Armour Glue Works, 3130 Benson St.; res., 3348 Dearborn St., Chicago, Ill. Sept. 22, 1905

DAVIS, LESLIE FOSTER, Secretary and Manager, West India Electric Co., Ltd., 151 Orange St., Kingston, Jamaica. Sept. 27, 1899

DAVIS, NELSON B., Electrical Draftsman, Westinghouse Electric and Mfg Co., Pittsburg, Pa. June 21, 1907

DAVIS, PHILIP W., Engineer of New England Office, The Electric Storage Battery Co., Boston; res., Cambridge, Mass. May 15, 1900

DAVIS, RICHMOND PEARSON, United States Military Academy, West Point, N. Y. Apr. 22, 1904

DAVIS, SOLOMON, Proprietor, The Conduit Wiring Co., 14 West 29th St., New York City. July 25, 1902

DAVIS, WILLIAM GRIFFITH, Storage Battery, Sales Engineer Westinghouse Machine Co., 10 Bridge St., New York City. Oct. 24, 1902

DAVIS, W. J., JR., Electrical Engineer, General Electric Co., Schenectady, N. Y. Mar. 20, 1895

DAVISON, GEORGE RUPERT, Edison Electric Illuminating Co., Boston; res., 83 Dix St., Dorchester, Mass. Apr. 27, 1906

DAVOUD, VAHRAM YETTOART, Locke Insulator Co., Victor, N. Y. Feb. 24, 1905

DAWSON, ARTHUR W., Superintendent, Michigan Lake Superior Power Co., Saulte Ste Marie, Mich. Jan. 26, 1906

DAWSON, JOSIAH, Contractor for Electric Light and Power, etc., Cuba Street Extension, Wellington, New Zealand. Jan. 9, 1901

DAWSON, WILLIAM FRANCIS, Designing Engineer, British Thomson-Houston Co., Ltd., Rugby, Eng. Dec. 15, 1905

DAY, CHARLES, Dodge & Day, Nicetown; res., Germantown, Philadelphia, Pa. May 20, 1902

DAY, MAXWELL W., Assistant Engineer, Power and Mining Department, General Electric Co., Schenectady, N. Y. Dec. 28, 1906

DAY, THOMAS HENRY, Electrical Inspector, Hartford Board of Fire Underwriters, 27 Pliny St., Hartford, Conn. Apr. 26, 1907

DAY, WINTERTON JAMES, Power and Mining Engineering Department, General Electric Co., Schenectady, N. Y. June 19, 1903

DEAN, GEORGE COOPER, Member of firm Johnston and Dean, 11 Pine St.; res., 823 West End Ave., New York City. May 17, 1904

DEAN, JOHN SWIFT, Railway Division, Engineering Dept., Westinghouse Electric and Mfg. Co.; Pittsburg, Pa. Nov. 23, 1906

DEAN, WALTER CLARK, Consulting Electrical Engineer, Bank of Commerce Building, Norfolk, Va. Sept. 17, 1901

DEAN, WILLIAM FAIRCHILD, Contracting Engineer, New Haven, Conn. Feb. 23, 1906

DEAN, WILLIAM TUCKER, Commercial Engineer, General Electric Co., Monadnock Blk.; res., 1029 Howard Ave., Chicago, Ill. Apr. 23 1903

DEAN, WILLIAM WARREN, Vice-president Dean Electric Co., Elyria, O. Nov. 21, 1902

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Dearborn, Richard Harold, Assistant Professor of Electrical Engineering, University of Oregon, Eugene, Ore. Jan. 25, 1907

DeBaufre, William Lane, Student, Lehigh University; res., 713 Broadway, So. Bethlehem, Pa. Apr. 26, 1907

De Blois, Lewis Amory, Electrical Engineer, California Powder Co., Wells Fargo Bldg., San Francisco, Cal. Sept. 25, 1903

de Castro, Americo Vieira, Chief Engineer, Electric Tramway Co., Porto Portugal. Mar. 25, 1904

de Chatelain, Mikail Andrejevitch, Professor of Electrical Engineering, Wasily Ostrow, 10 line No. 5, St. Petersburg. Nov. 23, 1900

Decker, Rudolph J., Consulting Electrical and Mechanical Engineer, Sao Paulo Ry. and Light Co., Sao Paulo, Brazil Feb. 26, 1904

Decker, Ward, Sterling Motor Car Co., 184 Water St.; res., 25 Lathrop Ave., Binghamton, N. Y. May 19, 1903

De Crow, Charles Edward, In charge of Power Apparatus, Output Dept., W. E. Co., 259 So. Clinton St., Chicago, Ill. Sept. 27, 1901

Deeds, Edward Andrew, Assistant General Manager National Cash Register Co., Dayton, O. Nov. 23, 1900

DeForest, Cornelius W., Chief Engineer, So. Covington & Cincinnati Street Railway Co., Newport, Ky. Mar. 1, 1907

Degen, Lewis, Rio de Janiero Tramway Light and Power Co., Rio de Janeiro, Brazil. Sept. 25, 1895

De Gress, Francis Barrett, Crocker-Wheeler Co., 39 Cortlandt St. New York City. Nov. 25, 1904

de Hoor-Tempis, Maurice, Professor, Royal University of Technical Sciences, Budapest II., Zsigmondutca 9, Hungary. Nov. 20, 1903

Delafield, Clarence E., Manager High Tension Division, Ohio Brass Co., Mansfield, Ohio. Apr. 23, 1903

Delafield, Eugene Livingston, Salesman and Estimator, W. E. Quimby Inc.; 44 E. 23d St., New York City. Mar. 29, 1907

de la Pena, Luis, General Manager, "Sociedad de Gasificacion Industrial," 13 Ologaza, Madrid, Spain. Mar. 24, 1905

Delaval, Jules Leon, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg; res., Wilmerding, Pa. June 19, 1903

Dellert, Joseph G., Student, Brooklyn, Polytechnic Institute; res., 76 St. Marks Ave., Brooklyn, N. Y. Jan. 25, 1907

De Long, James C., Engineer, United Gas Improvement Co., Broad and Arch Sts., Philadelphia, Pa. Jan. 27, 1905

Del Mar, William Arthur, Electrical Engineer. N. Y. C. & H. R. R.R.; res., 557 W. 141st St., New York City. Oct. 26, 1906

de Magalhaes, Frank Vasconcellos, Larkfield, N.Y. Jan. 25, 1907

De Mallie, James M., Sales Engineer, National Battery Co. res., 371 W. 120th St., New York City. Dec. 15, 1905

de Marchena, E., Chief Engineer, Compagnie Franciase, Thomson Houston, 10 Rue de Londres, Paris, France. June 19, 1903

Demarest, F. A., General Superintendent, Interstate Telephone Co., 18 So. Stockton St., Trenton, N. J. Feb. 26, 1904

Dempster, Thomas, Electrical Engineer, General Electric Co., Schenectady, N. Y. May 17, 1898

Denn, Howard Harper, Teacher in Mechanical Drawing, Drexel Institute, Philadelphia, Pa. Dec. 18, 1903

Denneen, Francis S., Commercial Engineer, Ohio Brass Co.. Mansfield, Ohio. Nov. 25, 1904

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DENNINGTON, ARTHUR ROSCOE, Assistant Principal, School of E. E., International Correspondence School, Scranton, Pa: Sept. 28, 1906

DENNISON, BOYD COE, Instructor, Cornell University res., Cornell Heights, Ithaca, N. Y. Jan. 26, 1906

DENNISON, EDGAR WALLACE, Edison Phonograph Works, Orange, N. J. June 19, 1903

DE NORDWALL, CHARLES FLESCH, London Director Allgemeine Elektricitats-Gesellschaft, 2 Observatory Gardens, London. Sept. 27, 1892

DENTON, ALPHEUS PENN, 810 S. 2d St., Leavenworth, Kansas. Dec. 28, 1906

DEPPELER, JOHN HOWARD, Inspector, N. Y. C. & H. R. R.R., New York City; res., 12 N. 16th St., East Orange, N. J. Dec. 28, 1906

DEREMO, LEONARD J., Consulting Engineer, Fourth National Bank Bldg.; res., College Hill, Cincinnati, Ohio. June 21, 1907

DESBLEDS, EDOUARD MARC, Surveyor and Clerk of Works, Public Works Department, Curepipe, Mauritius. Sept. 28, 1906

DE STA CECILIA, J. Felippi, Chief Electrical Engineer, Rua Alagoas, 56, Bello Horisonte, Minas, Brazil. Sept. 28, 1906

DEVENDORF, WILLIAM FREDERICK, Development Engineer, Western Electric Co.; res., 833 Lexington Ave., New York City. Sept. 28, 1906

DEVEREUX, WASHINGTON, Inspector, Philadelphia Fire Underwriters Association; res., 1625 N. 29th St., Philadelphia, Pa. Apr. 27, 1906

DEUTSCH, ISIDOR, Engineer, 92 Union Ave., Montreal, Ont. Apr. 28, 1905

DEWEY, THOMAS AUGUSTUS, 21 E. 8th St., Erie, Pa. Mar. 23, 1906

DEWHURST, RICHARD MILES, Electrical Engineer, Standard Underground Cable Co., Westinghouse Bldg., Pittsburg, Pa. Jan. 25, 1907

DE WOLF, ROGER DENNISON, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Nov. 20, 1903

D'HUMY, FERNAND EMILE, District Electrician, Postal Telegraph Cable Co. 253 Broadway, New York City. May 17, 1904

DIBBLE, BARRY, [*Local Secretary*] Engineer, Twin City Rapid Transit Co., 1317 Summit Ave., St. Paul, Minn. Jan. 26, 1906

DICKERSON, E. N., Attorney at-Law, 141 Broadway; res., 64 E. 34th St., New York City. Apr. 15, 1884

DICKERSON, RAYMOND, Draughtsman, New York Edison Co., New York City; res., 158 S. Eliot Pl., Brooklyn, N. Y. Mar. 29, 1907

DICKINSON, EDWARD CLARK, Burgess and Norton Mfg. Co., Geneva, Ill. Feb. 23, 1906

DICKINSON, EDGAR DRURY, Testing Dept., General Electric Co., res., 241 Liberty St., Schenectady, N. Y. Jan. 23, 1903

DICKINSON, HARRY HAMMOND, Erecting Engineer, The Arnold Co., Boland Building, 181 La Salle St., Chicago, Ill. July 28, 1903

DICKINSON, LEONARD P., Assistant Professor of Electrical Engineering, Lafayette College; res., 519 High St., Easton, Pa. Mar. 1, 1907

DICKINSON, RAYMOND NETTLETON, Automatic Refrigerating Co., 630 Capitol Ave., Hartford, Conn. Dec. 15, 1905

DICKINSON, WILLIAM NOBLE, JR., Otis Elevator Co., 17 Battery Place, New York City. July 28, 1905

DICKSON, JOHN LANE, Superintendent, Mount Union Light and Power Co., Mount Union, Pa. Oct. 26, 1906

DIEHL, HARRY EVERETT, Manufacturing Department, Telluride Power Co., Provo, Utah. June 21, 1907

DIETERICH, ALBERT EDGAR, Solicitor of Patents, with Fred G. Dieterich, 602 F St., N. W. Washington, D. C. Jan. 23, 1903

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DIETERICH, FRED G., Solicitor of Patents and Mechanical Expert, 602 F St., Washington, D. C. July 18, 1899

DILL, RAYMOND, Sales Department, Allis-Chalmers Co.; res., 2256 Madison Ave., Norwood, Ohio. Feb. 23, 1906

DILLON, EDWARD PAUL, Electrical Engineer, The Colorado Springs Electric Co., 107 E. Kiowa St., Colorado Springs, Col. Sept. 26, 1902

DILLON, ROY HODGSON, Inspector with F. O. Blackwell, 49 Wall St., New York, N. Y.; res., Normal, Ill. Aug. 25, 1905

DIMON, THEODORE, Telephone Engineer, Chicago Telephone Co., 227 Washington St., Chicago, Ill. Mar. 25, 1904

DINGLE, HOWARD, Sales Department, Crocker-Wheeler Co., res.; 37 Park Ave., East Orange, N. J. Mar. 29, 1907

DINHAM-PEREN, ARTHUR EDWARD HALLORAN, Br. W. E. & M. Co., Ltd., "Bealings" Southborne-on-Sea Christchurch, Hampshire, Eng. Jan. 25, 1907

DINKEY, ALVA C., Supt. Electric Dept., Homestead Steel Works, Munhall Pa. Feb. 17, 1897

DINSMORE, GEORGE FREDERICK, Treasurer, Hatch Accumulator Co., 60 State St., Boston, Mass. Jan. 26, 1906

DINSMORE, JOSEPH PAUL, Telephone Engineer, Western Electric Co., 259 S. Clinton St., Chicago, Ill. June 21, 1907

DINSMORE, SAMUEL C., Westinghouse Lamp Co., 510 West 23d St., New York City. Sept. 25, 1903

DIXON, JAMES, Electrical Engineer & Contractor, Vernon Ave., & 14th St., Long Island City, N. Y. Jan. 24, 1902

DIXON, WILL MONTAGUE, Chief Department of Electricity, Jamestown Exposition Pine Beach, Va. May 19, 1903

DODD, JOHN NEVINS, Westinghouse Electric & Mfg. Co.; res., Cedar St., Irwin, Pa. Feb. 27, 1903

DODDS, SAMUEL RENWICK, Instructor, Cornell University, Ithaca, N.Y. Sept. 28, 1906

DODGE, KERN, Dodge & Day, Nicetown; res., Germantown, Philadelphia, Pa. May 20, 1902

DOLKART, LEO, Telephone Engineer, Western Electric Co., Chicago, Ill. Feb. 23, 1906

DOLPH, JOHN CLEMENT, Manager, Insulating Varnish Department, Standard Varnish Works, 29 Broadway, New York City. Sept. 25, 1903

DONALDSON, JOHN MUIR, Commercial Engineer, British Thomson-Houston Co.; res., 29 Murray Road, Rugby, Eng. Oct. 28, 1904

DON CARLOS, HENRY C., Eureka Electric Co., Eureka, Utah; res., Clarksburg, Mo. Apr. 23, 1903

DONNAN, DAVID MCANALLY, Construction Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Jan. 27, 1905

DONOHOE, FRANCIS EUGENE, Sales Agent, American Electrical Works, 26 Cortlandt St.; res., Hotel Marseille, New York City Apr. 27,1906

DONSHEA, WILLIAM ISAAC, District Superintendent, The N. Y. Edison Co., 55 Duane St., New York City. Apr. 23, 1903

DOOLITTLE, CHARLES BENJAMIN, Supt. of Traffic, The Southern N. E. Telephone Co., 118 Court St., New Haven, Conn. Apr. 23, 1903

DOOLITTLE, CLARENCE E., Manager and Electrician, Roaring Fork Electric Light and Power Co., Aspen, Colo. May 15, 1895

DOOLITTLE, THOMAS B., Engineering Department, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. May 16, 1893

DOREMUS, CHARLES AVERY, *M.D.*, *Ph. D.*,55 W. 53d St., New York City. July 7, 1884

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DORNBUSCH, LOUIS CHARLES, 61 Hancock St., Brooklyn, N. Y. Dec. 19, 1902

DORR, CHARLES EDWIN, Electrical Engineer, Stanley Electric Mfg. Co.; res., 23 Westminster St., Pittsfield, Mass. Mar. 24, 1905

DORMAN, HARRY BOWERS, Chief Draftsman, Toledo Railway and Light Co., Toledo, Ohio. June 21, 1907

D'ORNELLAS, THOMAS VICENTE, Electrical Consulting Engineer, Peruvian Government, Sta Teresa 91, Lima, Peru. Mar. 1, 1907

DORNEY, JAMES JOSEPH, Westinghouse Electric and Mfg. Co.; res., 4248 West Belle Place, St. Louis, Mo. June 21, 1907

DOSTAL, JOHN FRANK, Member of Engineering Corps, Denver Gas and Electric Co., 1860 Logan Ave., Denver, Colo. Mar. 27, 1903

DOTY, ERNEST LAWRENCE, District Engineer, Westinghouse E. & M. Co., 780 Ellicott Square, Buffalo, N. Y. Sept. 25, 1903

DOTY, PAUL, Vice-president and General Manager, St. Paul Gas Light Co., St Paul, Minn. Mar. 25, 1904

DOUBLEDAY, HARRY M., Doubleday-Hill Electric Co., Lyons, N. Y. July 25, 1902

DOUBRAVA, HARRY WILFRED, Engineer, 220 Broadway, New York City. May 20, 1902

DOUD, CHARLES HAMILTON, Room 909, 150 Nassau St., New York City. Sept. 27, 1901

DOUGHERTY, CHARLES JAMES, Electrical Engineer, The Wm. Cramp & Sons Ship and Engine Building Co., Philadelphia, Pa. May 19, 1903

DOUGHERTY, PROCTOR L., Electrical Engineer, Treasury Department; res., 1427 Binney St., Washington, D. C. Dec. 19, 1902

DOUGLAS, EDWIN RUST, Superintendent, Adriance, Platt & Co.; res., 324 Church St., Poughkeepsie, N. Y. Jan. 23, 1903

DOUGLAS, EGBERT, Construction Engineer, General Electric Co., 667 Ellicott Square Building, Buffalo, N. Y. Apr. 23, 1903

DOVE, JOHN MAURY, JR., J. Maury Dove Co., Inc., 12th and F Sts., N. W., Washington, D. C. Mar. 23, 1906

DOW, HERBERT WILLIAM, Mechanical Engineer, Nordberg Mfg. Co., Milwaukee, Wis. May 19, 1903

DOW, JAMES CHASE, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Feb. 27, 1903

DOWIE, HORACE, with Westinghouse, Church, Kerr & Co., 8 Bridge St. New York City; res., 363 Jefferson Ave., Brooklyn, N. Y. Jan. 25, 1901

DOWNERD, HIROM S., Erecting Engineer, 2306 E. Michigan St., Indianapolis, Ind. June 19, 1903

DOWNES, LOUIS W., Vice-president and General Manager, The D. & W. Fuse Co., 407 Pine St., Providence, R. I. Nov. 22, 1899

DOWNING, P. M., Operating Engineer, California Gas & Elec. Corp., 925 Franklin St., San Francisco, Cal. June 24, 1898

DOWNING, RICHARD COLLINS, Niagara Lockport and Ontario Power Co., 518 Fidelity Bldg., Buffalo, N. Y. June 21, 1907

DOWNS, EDGAR SELAH, Tutor in Electrical Engineering Department, Columbia University, New York City. May 19, 1903

DOWNTON, CHARLES EDWARDS, Foreman of Apprentices, The Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Jan. 23, 1903

DRAKE, BERNARD MERVYN, Chairman, Drake & Gorham, Ltd., 66 Victoria St., London, S. W., Eng. Apr. 23, 1903

DRAKE, DAVID E., Sales Department, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City. June 19, 1903

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DRAKE, HERBERT WILLIAM, Assistant Wire Chief, American Telephone and Telegraph Co., 15 Dey St., New York City. Dec. 19, 1902

DRESBACH, HORATIO ARTHUR, Electrician, Van Dyck & Severn, 73 Amsterdam Ave., New York City. Apr. 28, 1905

DREHER, HERBERT CLARENCE, Superintendent, Edison Electric Illuminating Co., Tamaqua, Pa. June 21, 1907

DRESSEL, JOHN HATHAWAY, Naphet & Dressel, 605 Commercial Tribune Bldg., Cincinnati, Ohio. Sept. 27, 1901

DRESSER, CHARLES A., Supt., Kohler Bros., 1808 Fisher Bldg., Chicago, Ill. May 21, 1901

DRESSLER, CHARLES E., 17 Lexington Ave., New York City. Dec. 16, 1890

DRESSNER, VICTOR DORSEY, Student, Polytechnic Institute, Brooklyn; res., 202 W. 131st St., New York City. Jan. 25, 1907

DREW, WILFRID JAMES BARRE, Assistant Secretary and Treasurer, Canadian Society of Civil Engineers, Montreal, Que. Oct. 26, 1906

DREYFUS, EDWIN DAVID, Engineering Department, Chicago Edison Co., 470 Old Colony Building, Chicago, Ill. Feb. 23, 1906

DROGE, HARMAN GRABAU, Student, Columbia University, New York City; res., Flushing, N. Y. Feb. 24, 1905

DROHAN, T. E., Supt. of Shops, Northern Electric Mfg. Co., Madison, Wis. May 21, 1901

DRYER, ERVIN, Salesman and Engineer, Allis-Chalmers Co., 1522 First National Bank Building, Chicago, Ill. Feb. 28, 1902

DRYSDALE, DR. W. A., Consulting Electrical Engineer, 414 Hale Building, Philadelphia, Pa. Sept. 19, 1894

DUBOIS, ALEXANDER DAWES, Assistant to Engineer, Illinois Traction Co., Decatur, Ill. July 25, 1902

DUBOIS, DELAFIELD, General Electric Co.; res., 514 Smith St., Schenectady, N. Y. Sept. 28, 1906

DUBOIS, TUTHILL, General Electric Inspection Co., 237 Fulton St. Aug. 23, 1899

DUCKETT, ALONZO L., Arc Light Superintendent, Asheville Electric Co., Asheville, N. C. June 21, 1907

DUDLEY, EUGENE ELMER, Assistant Electrical Engineer, Quartermaster's Dept., Ft. Yellowstone, Wyoming. Oct. 24, 1902

DUER, JOHN V. B., Inspector, Electrical Superintendent's Office, L. I. R. R. Co., Long Island City. Mar. 29, 1907

DUFF, WILLIAM ARCHIBALD, Engineering Salesman, Canadian Westinghouse Co., Ltd., Winnipeg, Man. Feb. 23, 1906

DUFRESNE, BERNARD MAURICE, Erecting Engineer, Westinghouse E. & M. Co., Room 507, Westinghouse Bldg., Pittsburg, Pa. Sept. 25, 1903

DUNBAR, ROBERT V., Electrical Designer, Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. Mar. 25, 1904

DUNCAN, JOHN D. E., Engineer, with Sanderson & Porter, 31 Nassau St., [Life Member.] New York City. Mar. 20, 1895

DUNCAN, THOMAS, Vice-president and General Manager, Duncan Electric Mfg. Co., Lafayette, Ind. Oct. 17, 1894

DUNCAN, WILLIAM SYLVESTER, Engineer, Western Electric Co.; res., 2433 Ohio St., Chicago, Ill. Jan. 26, 1906

DUNN, CLIFFORD E., Patent Attorney, Dunn & Turk, Park Row Bldg., New York City; res., 12a Monroe St., Brooklyn, N. Y. Feb. 15, 1899

DUNN, KINGSLEY G., Hunt, Mirk & Co., Inc., 642 Ashbury St., San Francisco, Cal. Oct. 17, 1894

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DUNSTAN, ARTHUR ST. CHARLES, Professor Electrical Engineering, Ala. Polytechnic Institute, Auburn, Ala. Nov. 25, 1904

DUNWOODY, HENRY H. C., 1522 31st St., Washington, D. C. May 17, 1904

DURANT, EDWARD, Electrical Engineer, 115 East 26th St., New York City. Nov. 15, 1892

DURANT, GEO. F., General Manager Bell Telephone Co., of Missouri, Telephone Building, St. Louis, Mo. Apr. 15, 1884

DURRAN, RICHARD THOMAS, Manager, A. E. G, Urbesee Abteiling Friedrich Karl ufer 2/4 Berlin N. W., Ger. Oct. 27, 1905

DUSMAN, JOHN F., Superintendent Electrical Equipment, United E. L. & P. Co., 30 So. Eutaw St., Baltimore, Md. May 19, 1903

DWIGHT, THEODORE, Asst. Secy. Amer. Inst. of Mining Engrs., 29 W. 29th St.; res., 103 W. 55th St., New York City. Jan. 23, 1903

DYER, ERNEST I., Manager, Charles C. Moore & Co., Engineers, Inc., Mutual Life Building, Seattle, Wash. Jan. 25, 1899

DYKE, OWEN ARTHUR WYNNE, Electrical Contractor, 90 St. George's St.; Capetown, South Africa. Sept. 27, 1901

DYOTT, GEORGE MILLER, Engineer, Westinghouse Electric and Mfg. Co.; res., 6837 Thomas St., E. E., Pittsburg, Pa. Nov. 23, 1906

DYSON, ALFRED HARTWELL, Engineer, 670, 308 Dearborn St., Chicago, Ill. Jan. 23, 1903

DYSTERUD, EMIL, Superintendent and General Manager, Electric Light and Power Co., Monterey, Nuevo Leon, Mexico. July 26, 1900

EASTHAM, MELVILLE, Electrician, Willyoung & Gibson, 40 W. 13th St., New York City. Sept. 22, 1905

EASTMAN, GEORGE NIAL, In charge of Testing Laboratory, Chicago Edison Co., 139 Adams St., Chicago, Ill. Nov. 22, 1901

EATON, HOWARD FRENCH, Mechanical and Electrical Draftsman, Stone & Weber, 147 Milk St., Boston, Mass. Feb. 27, 1903

EATON, RALPH WALDO, Commercial Engineer, Westinghouse Electric and Mfg. Co.; res., Technology Chambers, Boston, Mass. Apr. 26, 1907

EBERHARDT, ELMER GOULD, Sales Department, Westinghouse Electric & Mfg. Co., Gorham Building, Hazleton, Pa. Oct. 28, 1904

EBERHARDT, OTTO IMMANUEL, Sales Department, Westinghouse Electric & Mfg. Co., Land Title Building, Philadelphia, Pa. Dec. 28, 1906

EDDY, H. C., District Manager, American District Steam Co., 1334 Monadnock Building, Chicago, Ill. June 20, 1894

EDDY, HARRY CLIFFORD, Inspector Electrical Department, D. of C. District Building, Washington, D. C. Feb. 24, 1905

EDDY, HORACE T., Professor of Electrical Engineering, University of Cincinnati, Cincinnati, Ohio. May 21, 1901

EDDY, LYNNE W., Student, Western Electric Co., Hawthorne, Ill. Nov. 23, 1906

EDGAR, HARRY THOMAS, 2d Vice-president, Manager Northern Texas Traction Co., Ft. Worth, Tex. Feb. 27, 1903

EDMANDS, I. R., Works Manager, Union Carbide Co., 157 Michigan Ave., Chicago, Ill. June 23, 1897

EDMANDS, SAMUEL SUMNER, Instructor, Applied Electricity, Pratt Institute, Brooklyn, N. Y. Mar. 22, 1901

EDMONDS, SAMUEL OWEN, Patent Lawyer, 32 Liberty St.; res., Lawrence Park, Bronxville, N. Y. July 28, 1903

EDMUNDS, CHARLES KEYSER, Professor of Physics, Canton Christian College, Canton, China. Sept. 25, 1903

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EDSTROM, JOHANNES SIGFRID, General Manager, Allmanna Svenska Electric Co., Westerås, Sweden. May 19, 1903

EDWARDS, CHARLES GRIFFIN [*Local Secretary*], Assistant Engineer, Electrical Commission, City Hall, Baltimore, Md. May 17, 1904

EDWARDS, CLIFTON V., Patent Lawyer, 2 Rector St., New York. Nov. 22, 1899

EDWARDS, JAMES P., Assistant Electrical Engineer, Postal Telegraph Cable Co., 608 Prudential Building, Atlanta, Ga. Apr. 19, 1892

EDWARDS, JOSEPH BLACKBURN, Supt. Kellogg Switchboard and Supply Co., Congress and Green Sts., Chicago, Ill. Jan. 23, 1903

EGLIN, JAMES MEIKLE, Chief of Electric Dept. Edison Electric Light Co. 10th and Sansom Sts., Philadelphia, Pa. July 26, 1900

EGLINTON, WILLIAM MCNICOLL, Compania Electria de Concepcion. Concepcion, Chili. Feb. 27, 1903

EHRBAR, LOUIS HARVEY, Engineer, Subway Construction, New York Telephone Co., 15 Dey St., New York City. Sept. 28, 1906

EHRENREICH, JAMES JACOB, Contracting Electrical Engineer, 503 Fifth Ave., New York City. June 19, 1903

EHRBT, CORNELIUS DALZELL, 2116 New Land Title Building, Philadelphia, Pa. Jan. 24, 1902

EHRHART, RAYMOND NELSON, The Westinghouse Machine Co.; res., 7612 Edgerton Ave., Pittsburg, Pa. Mar. 27, 1903

EISENBEIS, WALTER HERMAN, Canadian Westinghouse Electric and Mfg. Co., Lawlor Building, Toronto, Ont. Dec. 19, 1902

EKBERG, WILLIAM ANTON, 33 Second St., San Francisco, Cal. Sept. 22, 1905

EKERN, EMIL ALFRED, Telluride Power Co., Grace, Idaho. Jan. 29, 1904

EKSTRAND, CHARLES, Engineer, Warner Sugar Refining Co., Edgewater, N. J. Apr. 25, 1902

EKSTROM, AXEL, Consulting Electrical Engineer, Delaware Hudson Ry., Co., Albany, N. Y. June 17, 1890

ELDEN, LEONARD LORD, Chief Electrician, Edison Electric Illuminating Co. of Boston, 3 Head Pl.; res., Dorchester, Mass. Apr. 23, 1903

ELEY, JOSIAH NORFLEET, Electrician, Ludwig & Co., 511 Empire Bldg., Atlanta, Ga. Feb. 28, 1902

ELLARD, JOHN W., J. L. Blackwell & Co., 801 Continental Building, Baltimore, Md. June 23, 1897

ELLINGER, EDGAR, Electrical Engineer, L. K. Comstock & Co., 114 Liberty St., New York City. Apr. 25, 1902

ELLIOTT, ALLMAND BLOW, Vice-president and Treasurer, Witherbee Igniter Co., 541 W. 43d St., New York City. Oct. 27, 1905

ELLIOTT, ARTHUR H., Engineer-Chemist, Consolidated Gas Co., 4 Irving Place, New York City. Mar. 23, 1906

ELLIOTT, ELMER G., Construction Engineer, Selby Smelting & Lead Co., Selby, Cal. May 21, 1902

ELLIOTT, GEORGE WILSON, Electrical World; res., Llewellyn Park, Orange, N. J. June 14, 1905

ELLIOTT, HOWARD STICKNEY, Milwaukee Electric Railway and Lighting Co., Milwaukee, Wis. Apr. 26, 1907

ELLIOTT, THOMAS, Chief Engineer, Cincinnati Traction Co., Cincinnati, O. May 19, 1903

ELLIOTT, WILLIAM HENRY, Signal Engineer, N. Y. C. & H. R. R. R., Room 1245, Grand Central Station, New York City. Dec. 15, 1905

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ELLIS, CLARENCE HEYWARD, Superintendent, City Electric Light Plant, Tallahassee, Florida. Mar. 24, 1905

ELLIS, JOHN, Manager, The Lonsdale Co.'s Electric Light Plant, Lonsdale R. I. Apr. 26, 1899

ELLS, FREDERICK WILLIAM, Secretary and Engineer, Northwestern Mfg. Co., Milwaukee, Wis. July 19, 1904

ELMER, WILLIAM, JR., Master Mechanic, 28th St. Shops, Pittsburg, Pa. Mar. 18, 1890

ELSHOFF, BERNARD, Superintendent Electrical Department, Allis-Chalmers Co., Milwaukee, Wis. Feb. 27, 1903

ELWELL, DAVID, Engineer, Railway Construction Department, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Apr. 26, 1907

ELY, CHARLES CADWALLADER Constructing Engineer, Kansas City and Western Railway, Rosedale Station, Kansas City, Mo. Apr. 26, 1907

ELY, WM. GROSVENOR, JR., Supt. of Construction, General Electric Co.; res., Lenox Road, Schenectady, N. Y. Mar. 21, 1893

EMERICK, LOUIS W., Vice-president and General Manager, Fulton Light, Heat and Power Co., Fulton, N. Y. Aug. 13, 1897

EMBERSON, HENRY BENNETT, Engineer, General Electric Co.; res., 216 Parkwood Blvd., Schenectady, N. Y. Dec. 28, 1906

EMERSON, LUTHER LEE, Manager, Clark and McMullen, 20 Broad St., New York City. Nov. 25, 1904

ENDICOTT, WINTHROP TINGLEY, Assistant on Electrolytic Investigation Boston Elevated Railway Co., Boston, Mass. Mar. 1, 1907

ENDRES, KENNETH WINDRAM, Electrical Engineer, American Telephone & Telegraph Co., 15 Dey St., New York City, Mar. 1, 1907

ENGEL, JOHN GUSTAV, Electrical Engineering Department, Twin City Rapid Transit Co., Minneapolis, Minn. Mar. 1, 1907

ENGELHORN, FRANK JOSEPH, Superintendent of Electrical Dept., Atlin Consolidated Mining Co., Atlin, B. C. May 19, 1903

ENGLAND, PAUL WILLARD, Assistant Engineer, Bell Telephone Co., 11th and Arch Sts., Philadelphia, Pa. Mar. 25, 1904

ENGLISH, THOMAS FULTON, Superintendent Union Light, Heat and Power Co., Covington, Ky. Oct. 27, 1905

ENSLEN, EUGENE FLYNN, JR., Electrical Engineering Assistant, Ford Bacon and Davis, Birmingham, Ala. Oct. 28, 1904

ENSTRÖM, ALEX FREDRIK, Professor Royal Technical Academy, 99 Regeringsgatan, Stockholm, Sweden. Nov. 25, 1904

ENTZ, JUSTUS BULKLEY, Vice-president Electric Vehicle Co., Hartford Conn. Jan. 7, 1890

ENTZ, THEODORE B., Branch office manager, Electric Storage Battery Co., 817 Wainwright Building, St. Louis, Mo. Feb. 26, 1904

EPSTEIN, JOSEPH, Engineer in Chief, Elektrizitats-Aktiengesellschaft Leerbachstressa 32, Frankfort am Main, Germany. Mar. 25, 1904

ERBEN, H. F. T., Designing Engineer, General Electric Co., Schenectady, N. Y. Aug. 22, 1902

ERISMAN, OSCAR, Engineer, General Electric Co.; res., 23 Glenwood Blvd., Schenectady, N. Y. Nov. 23, 1906

ERWIN, FRANK BENNETT, Electrical Engineer, Westinghouse E. & M. Co., 11 Pine St., New York City. Jan. 3, 1902

ESLING, ALBERT, Sales Manager, R. E. T. Pringle Co., 33 Vincent St., W., Toronto, Ont. Nov. 20, 1903

ESTABROOK, HARRY CROWNINGSHIELD, Construction Foreman, Stanley G. I. Electric Mfg. Co., Pittsfield, Mass. May 15, 1905

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ESTERLINE, J. WALTER [*Local Secretary*], Instructor Electrical Engineering, Purdue University, Lafayette, Ind. Mar. 28, 1900

ESTES, JAMES WALTER, Contract Department, Crocker-Wheeler Co., Ampere, N. J. Apr. 27, 1906

ETHERIDGE, HARRY, Asst. Supt. Allegheny Co. Light Co.; res., 1906 Jenny Lind St., McKeesport, Pa. Jan. 23, 1903

ETHERIDGE, LOCKE, *M.E.*, Electrical Engineer, 427 Monadnock Bldg.; res., 44 E. 50th St., Chicago, Ill. Oct. 17, 1894

ETTRUP, LAWRENCE, Consulting Engineer, Sacramento Ashburton Mining Co., Room 36, Physician Bldg., Sacramento, Cal. Feb. 26, 1904

EVANS, HERBERT S., Professor, University of Colorado, Boulder, Colo. Nov. 24, 1905

EVANS, ROBERT PENNAL, JR., Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. June 21, 1907

EVANS, WALTER HUBERT, Draftsman, Central California Traction Co.; res., 435 East Park St., Stockton, Cal. Nov. 23, 1906

EVANS, WILLIAM ALBERT, Assistant Laboratorian, Philadelphia Electric Co., 122 Arch St., Philadelphia, Pa. Mar. 25, 1904

EVELAND, PORTER, Leadville Light & Power Co., 114 E. 8th St., Leadville, Colo. June 19, 1903

EVELETH, CHARLES E., Assistant Engineer, General Electric Co.; res., 111 Parkwood Blvd., Schenectady, N. Y. Nov. 23, 1906

EVELETH, CHARLES MIRICK, Engineering Dept., American Telephone and Telegraph Co., 22 Thames St., New York City. May 17, 1904

EVERETT, CHARLES EDWARD, Electrical Operator, Interborough Rapid Transit Co., 100 Division St., New York City. Sept. 28, 1906

EVERETT, SAMUEL HARRISON, JR., Electrical Engineer, Gould Storage Battery Co., 347 Fifth Ave., New York City. May 14, 1906

EVERIT, EDWARD HOTCHKISS, Engineer, The So. N. E. Telephone Co., 641 Whitney Ave., New Haven, Conn. Jan. 3, 1902

EVERS, EDWARD PAUL, Motor Tester, Wagner Electric Mfg. Co., St. Louis, Mo. Apr. 27, 1906

EWING, GEORGE CLINTON, Electrical Railway Supplies, 131 State St., Boston, Mass. Mar. 27, 1903

EWING, THOMAS, JR., Ewing, Whitman & Ewing, 67 Wall St., NewYork; res., Yonkers, N. Y. July 19, 1904

EYRE, MANNING K., Westinghouse Lamp Co., 510 W. 23d St., New York City. Oct. 17, 1894

FACCIOLI, GIUSEPPE, Electrical Engineer, General Electric Co., Great Barrington, Mass. July 19, 1904

FAHNESTOCK, ERNEST BENJAMIN, Vice-president and G. M., Fahnestock Electric Co., 129 Patchen Ave., Brooklyn, N. Y. Apr. 23, 1903

FAHNESTOCK, J. HARVEY, Engineering Department, Wisconsin Telephone Co., Milwaukee, Wis. July 19, 1904

FAHY, FRANK P., Draftsman, Pennsylvania Railroad Co.; res., 1408 7th Ave., Altoona, Pa. May 15, 1905

FAIRBANKS, GEORGE BANKER, Salesman, Westinghouse Electric and Mfg. Co., 314 Occidental Ave., Seattle, Wash. Mar. 24, 1905

FAIRBANKS, ROBERT PAYNE, Power Station Superintendent, Telluride Power Co., Provo, Utah. Apr. 23, 1903

FAIRCHILD, ALBERT ROYAL, Property Man, Twin City Rapid Transit Co.; res., 1034 S. E. 17th Ave., Minneapolis, Minn. Nov. 24, 1905

FAIRCHILD, WALTER LOWE, Consulting Engineer, Mills Building, New York City. Oct. 24, 1902

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FALLGATTER, HOMER BECK, Wire Chief, Johnstown Telephone Co., 644 Main St., Johnstown, Pa. May 15, 1905

FANSLER, PERCIVAL ELLIOT, *B. S.*, J. G. White & Co., 43 Exchange Pl., New York City. Mar. 28, 1902

FARLEY, J. WALDRON, Transformer Designer, Westinghouse E. & M. Co., Pittsburg, Pa. Sept. 25, 1903

FARMER, FRANK MALCOLM, Electrical Testing Laboratories, 80th St. & East End Ave., New York City. Nov. 21, 1902

FARMER, IV. THOMAS, Engineer, Consolidated Car Heating Co.; res., 355 State St., Albany, N. Y. Oct. 26, 1906

FARNELL, WILLIAM CLEMENT FOSTER, Head Final Inspector, Western Electric Co., New York City. Mar. 1, 1907

FARNSWORTH, ARTHUR J., Supt. of Construction, Stone and Webster, Engineering Corp. Jacksonville, Florida. Jan. 16, 1895

FARRAND, DUDLEY, General Manager, United Electric Company of New Jersey; 207 Market St., Newark, N. J. July 26, 1900

FARRAR, EDWARD LESLIE, Induction Motor Dept., General Electric Co.; res., 791 State St., Schenectady, N. Y. Nov. 23, 1906

FARROW, PERCIVAL ROBERT, Chief Operator, Kammistiquia Power Co., Kakabeka Falls, Ont. Apr. 26, 1907

FARWELL, FRANKLIN MAGINNIS, 109 S. 6th St., Duquesne, Pa. May 14, 1906

FARWELL, HAROLD GILBERT, 30 7th Ave., New York City. Apr. 23, 1903

FASHBAUGH, WILLIAM N., Electrician, Western Union Telegragh Co., 195 Broadway; res., 545 W. 148th St., New York City. July 26, 1907

FAULDER, ALFRED JOSEPH, Chief Clerk, Engineering Department, New York Tel. Co., 15 Dey St., New York City. Mar. 29, 1907

FAWCETT, WALLACE H., General Electric Co.; res., 8 Union St., Schenectady, N. Y. Aug. 22, 1902

FAY, THOMAS J., J. M. Ellsworth, 518 W. 22d St., New York City. June 26, 1891

FEATHER, ROBERT JOHN, Electrician, Columbus Railway and Light Co., 573½ N. High St., Columbus, O. Mar. 25, 1904

FECHHEIMER, CARL J., Assistant Engineer, Bullock Electric Mfg. Co.; res., 3442 Reading Road, Cincinnati, O. Dec. 15, 1905

FEICHT, RUSSELL, STIMSON Electrical Engineer, Westinghouse Electric Mfg. Co., Pittsburg, Pa. Apr. 28, 1905

FEILDEN, THEODORE JOHN VALENTINE, Editor-in-chief *The Electrical Magazine*, 4 Southampton Row, London, W. C. Nov. 25, 1904

FELDMANN, CLARENCE, Professor Electrical Engineering, Technical High School, Delft, Holland. May 19, 1903

FELLOWS, HENRY WALLACE, Consulting and Construction Engineer, Goldendale, Wash. May 19, 1903

FENN, ERNEST JAMES, Partner, Steuart & Fenn, Dundin, N. Z. Apr. 22, 1904

FERGUS, WILLIAM LOVEDAY, Consulting Mechanical and Electrical Engineer, 1509 Fisher Building, Chicago, Ill. May 19, 1903

FERGUSON, JOHN, Partner, McLaren and Ferguson; res., 43 Dalhousie St., Glasgow, Scotland. Sept. 28, 1906

FERGUSON, OLIN JEROME, Asst. Professor of E. E., Union College; res., 1007 Nott St., Schenectady, N. Y. Nov. 24, 1905

FERGUSON, SAMUEL, Engineer, General Electric Co., Schenectady, N. Y. Jan. 3, 1902

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FERGUSON, WILLIAM AGUSTINE, Electrical Engineer, Mexican Light and Power Co., Ltd., Mexico City. Oct. 28, 1904

FERNANDEZ, WILLIAM TALANERA, Foreman, Electrical Operating Dept., N. Y. Edison Co., 38th St. & 1st Ave., New York. May 19, 1903

FERRIN, ARTHUR W., Consolidated Car Heating Co., 150 N. Pearl St., Albany, N. Y. June 15, 1904

FERRIN, EDWARD EUGENE, Foreman, Installing Department, Western Electric Co., Dallas, Texas. Sept. 28, 1906

FERRIS, ROBERT MURRAY, Engineer, The New York Telephone Co., 15 Dey St., New York City. Feb. 28, 1902

FERRY, MONTAGUE, Engineer, S. G. McMeen; res., 787 Market St., San Francisco, Cal. Apr. 26, 1907

FETHERLING, HERSCHEL G., Engineer, Blaisdell Filtration Co., Los Angeles and New York City. Dec. 18, 1903

FEUERSTEIN, SIEGMUND, Electrical Engineer, Rochester and Southern Construction Co., Rochester, N. Y. Sept. 28, 1906

FIELD, ALLAN BERTRAM, Bullock Electric Mfg. Co.; res., 4316 Forest Ave., Station H, Cincinnati, O. May 19, 1903

FIELD, ARTHUR W., 11 Johnson St., Waterbury, Conn. Aug. 22, 1902

FIELD, ROY ALBRIGHT, Superintendent, Rome Gas, Electric Light and Power Co., Rome, N. Y. Dec. 15, 1905

FIELDING, FRANK E., Chemist and Assayer, Virginia City. Nev. [Life Member.] Sept. 6, 1887

FIELDING, GEORGE THOMAS, JR., General Electric Co.; res., 1234 Union St., Schenectady, N. Y. Sept. 28, 1906

FIELDING, PHILIP HARRISON, Inv., Electrical Specialties, 60 Sea View Ave., S. Norwalk, Conn. July 28, 1903

FIEUX, ERNEST D., De La Vergne Machine Co., East 138th St.; res., 225 Riverside Drive, New York City. Mar. 1, 1907

FINCH, HERBERT ISAAC, [*Local Secretary*] Assist. Supt. The Emerson Electric Mfg. Co., St. Louis, Mo. Apr. 23, 1903

FINE, JAMES MORRELL, Foreman, Testing Department, De Laval Steam Turbine Co., Trenton, N. J. Feb. 24, 1905

FINLAY, WALTER STEVENSON, JR., Assistant Engineer to Supt. of M. P., Interborough Rapid Transit Co., New York City. Sept. 28, 1906

FINNEY, ALFRED CARREL, Switchboard Inspector, General Electric Co.; res., 54 Front St., Schenectady, N. Y. Apr. 26, 1907

FINNEY, JOHN H., Manager Aluminum Co. of America, National Bank of Commerce Building, St. Louis, Mo. Sept. 26, 1902

FINZI, GEORGE, General Manager, Officine Elettro-Terroviarie, 24 Piazza Castello, Milano, Italy. Mar. 27, 1903

FIRMAN, LEO DORSEY, Assistant Inspector of Electric Lighting, Electrical Bureau; res., 1730 Girard Ave., Philadelphia, Pa. Sept. 28, 1906

FIRTH, WM. EDGAR, Chief Engineer, The Midvale Steel Co., Nicetown, Phila.; res., 7203 Boyer St., Germantown, Pa. Mar. 25, 1896

FISH, FRED ALAN, Associate Prof. of Electrical Engineering, Iowa State College, Ames, Iowa. Mar. 28, 1900

FISH, FREDERICK PERRY, Fish, Richardson, Herrick & Neave, 84 State St. Boston; res., Brookline, Mass. Mar. 28, 1902

FISHBACK, FREDERICK R., Salesman, Electric Controller and Supply Co.; res., 7617 Linwood Ave., Cleveland, Ohio. July 26, 1907

FISCHER, ADOLPH LOUIS, Assistant, Transformer Department, Thomson, Houston Electric Co., W. Lynn, Mass. Apr. 26, 1907

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FISHER, BENJAMIN FRANKLIN, JR., Electrical Engineer, Q. M. G. O., U. S. Government, Washington, D. C. Jan. 29, 1904

FISHER, GEORGE EDWARD, Inspector, Associated Factory Mutual Fire Ins. Co., Room 510, 31 Milk St., Boston, Mass. Apr. 23, 1903

FISHER, HOWARD SHREVE, Westinghouse Electric and Mfg. Co., 11 Fire St., New York City. Dec. 19, 1902

FISKE, WARREN HERBERT, Electrical Engineer, Mexico Tramways Co., Mexico, D. F., Mex. July 28, 1903

FISKEN, JOHN BARCLAY, Superintendent Light and Power System, The Washington Water Power Co., Spokane, Wash. Apr. 23, 1903

FITTS, CLARENCE DUDLEY, Electrician, Oakville Co., Oakville, Conn. Nov. 20, 1903

FITZ, ERVIN MOUL, Electrical Engineer, M. P. Dept., Pennsylvania Lines West of Pittsburg, Columbus, O. Sept. 25, 1903

FITZGERALD, THOMAS, JR., Cincinnati Traction Co., Cincinnati, O. Jan. 3, 1902

FITZHUGH, WM. H., Supt. Bay City Electric Plant, 2230 Center Ave., Bay City, Mich. Apr. 27, 1898

FLAGG, RAY, Electrical Engineer's Assistant, Wagner Electric Mfg. Co. 2017 Locust St., St. Louis, Mo. Sept. 28, 1906

FLATHER, JOHN J., Professor of Mechanical Engineering, University of Minnesota, Minneapolis, Minn. Apr. 19, 1892

FLEET, JAMES A., General Superintendent, Consolidated Electric Light Co., Portland, Maine. Apr. 26, 1907

FLEMING, DANIEL J., American Appraisal Co., 43 Exchange Place, New York City. Sept. 28, 1906

FLEMING, JOHN BRECKENRIDGE, Mechanical Engineer, Joshua Herdy Iron Works, San Francisco, Cal. Apr. 27, 1898

FLEMING, RICHARD, Designing Engineer, General Electric Co., Lynn; res., Swampscott, Mass. Jan. 24, 1902

FLEMING, THOMAS JOSEPH, Electrical Engineer, Agar, Cross & Co. 124 Call Defensa 128, Buenos Ayres, S. A. Sept. 25, 1903

FLESHIEM, ROBERT STEPHENSON, Sales Engineer, Allis-Chalmers Co., 1505 First National Bank Bldg., Cincinnati, O. Apr. 26, 1907

FLETCHER, CHARLES WILLIAM, Morse Chain Co., Ithaca, N. Y. Jan. 27, 1905

FLETCHER, RAYMOND, FENNIMORE Electrical Engineer, McMaster & Fletcher, 338 E. State St., Columbus, O. Apr. 22, 1904

FLICKINGER, JOHN TRESSLER, with General Superintendent, General Electric Co., Schenectady, N. Y. Sept. 25, 1903

FLIESS, ROBERT ANTON, 44 Chestnut St., East Orange, N. J Mar. 23, 1898

FLINT, JAMES J., President, The Flint-Lomax Electric and Mfg. Co., 1400 Delgany St.; res., Berkeley, Denver, Colo. Mar. 27, 1903

FLINT, LOUIS JOSEPH, Kellogg Switchboard and Supply Co., Chicago, Ill. June 21, 1907

FLOWERS, ALAN ESTIS, Instructor, University of Missouri, Columbia Club, Columbia, Mo. Nov. 25, 1904

FLOY, HENRY, Consulting Electrical and Mechanical Engineer, 220 Broadway, New York City; res., E. Orange, N. J. May 17, 1892

FLOYD, WALTER CLARENCE, Assistant Superintendent of Construction, Emer-Hopkins Co., Columbus, O. Feb. 24, 1905

FOLEY, HIRAM SAINE, Superintendent, San Ildefonso Division, Mexican Light and Power Co., Mexico City, Mex. Jan. 25, 1907

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FOOT, BENJAMIN DEAN, Electrical Engineer, G. E. Co.; res., 629 Liberty St., Schenectady, N. Y. Oct. 26, 1906

FOOTE, FERDINAND JOHN, Engineering Department, Westinghouse Electric and Mfg. Co., Cincinnati, O. Oct. 23, 1903

FOOTE, HORACE BURT, Electrical Engineer, General Electric Co., Schenectady, N. Y. Mar. 29, 1907

FOOTE, STANLEY CLIFFORD, Electrician, Long Arm System Co., Cleveland, O. Apr. 27, 1906

FORD, CHARLES W., General Superintendent, Oklahoma City Ry. Co. 120 Grand Ave., Oklahoma City, Okla. Feb. 24, 1905

FORD, FRANK R., *M. E.*, Consulting Engineer, Ford, Bacon & Davis 115 Broadway New York City. Mar. 25, 1896

FORD, HANNIBAL C., 1318 East Genesee St., Syracuse, N. Y. Feb. 24, 1905

FORD, WALTER STEBBINS, Instructor, Cornell University; res., 804 E. Seneca St., Ithaca, N. Y. Dec. 15, 1905

FORD, WM. SPENCER, 4 Howard St., Melrose ,Mass. June 7, 1892

FORMAN, PARIS RALPH, Mechanical Engineer, Burdett-Rowntree Mfg. Co., 85 W. Jackson St., Chicago, Ill. Apr. 26, 1907

FOREMAN, WALTER EVEREST, District Engineer, Westinghouse E. & M Co., Candler Building, Atlanta, Ga. Mar. 25, 1904

FORSYTH, JOSEPH C., Chief Inspector, Electrical Dept., The N. Y. Board of Fire Underwriters, 32 Nassau St., New York City. Apr. 23, 1903

FORSYTHE, WILLIAM CRAIG, Superintendent, Mobile Electrical Supply Co., Mobile, Ala. Dec. 23, 1904

FORTESCUE, CHARLES LE GEYT, Electrical Designer, Westinghouse E. & M. Co., Pittsburg; res., Wilkinsburg, Pa. Jan. 23, 1903

FOSTER, FRANCIS PERRY, Superintendent, Fire Alarm Telegraph, Corning Fire Department, City Hall, Corning, N. Y. Dec. 23, 1904

FOSTER, FREDERICK HENRY, Engineering Department, Hamilton Electric Light and Cataract Power Co., Hamilton, Ont. June 19, 1903

FOSTER, GEORGE BEERS, District Manager, Allis-Chalmers Co., Milwaukee, Wis. Feb. 27, 1903

FOSTER, MARCUS LUCUEAS, JR., West Electric Co., Montgomery, Ala. Dec. 28, 1906

FOSTER, MORTIMER BRISTOL, Secretary and Treasurer, M. B. Foster Electric Co., 949 Broadway, New York City. Mar. 29, 1907

FOSTER, WILLIAM JAMES, Design Engineer, General Electric Co.; res., 2 Douglas Road, Schenectady, N. Y. Apr. 26, 1907

FOURNIER, GEORGE HENRY, Erecting Engineer, Westinghouse Electric and Mfg. Co., Baltimore, Md. Mar. 1, 1907

FOWLE, FRANK FULLER, Manager, Operating Dept., American Tel. and Tel. Co., Room 441, 105 Quincy St., Chicago, Ill. Dec. 19, 1902

FOWLER, CLARENCE PARKES, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 29, 1907

FOWLER, GEO. W., Electric Expert, Shelby Electric Co., 32 Frankfort St., New York City; res., Westfield, N. J. Oct. 24, 1900

FOWLER, MYRON MARSHALL, Electrical Engineer, Western Electric Co. 259 South Clinton St., Chicago, Ill. Apr. 23, 1903

FOX, MAURICE EDWARD, Student, Polytechnic Institute, Brooklyn; res. Hewletts, L. I., N. Y. Jan. 25, 1907

FOX, THOMAS EDWARD, Superintendent Electric Lighting Plant, Consolidated Railway Co., Greenwich, Conn. June 21, 1907

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FOX, WALTER GORDON, Assistant Chief Engineer, Ferrocarril al Curaray, 14 West 84th St., New York City. June 21, 1907

FOX, WILLIAM A., Secretary, Chicago Edison Co., 139 Adams St., Chicago, Ill. May 19, 1903

FOYSTER, ARTHUR HENRY, Electricity Dept., Edinburgh Corporation; res., 1 Dewar Pl., Edinburgh, Scotland. Oct. 27, 1905

FRANCIS, JOSEPH SIDNEY, Engineer, Bell Telephone Co. of Philadelphia, N. E. cor. 11th and Filbert Sts., Philadelphia, Pa. Mar. 29, 1907

FRANCISCO, FERRIS LE ROY, Supervising Electrician, Consolidated Tobacco Co.'s., 111 5th Ave., New York City. May 17, 1904

FRANCISCO, M. J., President and General Manager, Rutland Electric Light Co., Rutland, Vt. June 17, 1890

FRANK, AUGUSTUS ALPHONSUS, Engineering Department, New York Telephone Co., 15 Dey St., New York City. Jan. 23, 1903

FRANK, JOHN JACOB, Transformer Designing Engineer, General Electric Co.; res., 107 Elmer Ave., Schenectady, N. Y. Aug. 25, 1905

FRANKENBERG, JOHN THEODORE, Chief Engineer, Providence Telephone Co., Providence, R. I. July 26, 1907

FRANKENFIELD, BUDD, Engineering Department, Bullock Electric Mfg. Co., Cincinnati, O. Feb. 17, 1897

FRANKLIN, EMERSON LORAN, Assistant Superintendent, Easton Gas and Electric Co., 140 Ferry St., Easton, Pa. Mar. 24, 1905

FRANKLIN, MILTON W., *M.D.*, Electrical Engineer, 217 E. 23d St.; res., 206 W. 106th St., New York City. Oct. 27, 1905

FRANKLIN, THOMAS Z., Engineer, Underwriters' Association of the Middle Department, 316 Walnut St., Philadelphia, Pa. Apr. 27, 1906

FRANTZ, HOWARD M., Manager Electrical Department, H. W. Johns Manville Co., 173 Randolph St., Chicago, Ill. Jun 21, 1907

FRANTZEN, ARTHUR, Electrical Engineer and Contractor, 92 W. Van Buren St.; res., 1944 Kenmore Ave., Chicago, Ill. Feb. 21, 1894

FRASER, JAMES WM., Southern Power Co., Charlotte, N. C. May 21, 1901

FRASER, ROBERT M., Draftsman, Westinghouse, Church, Kerr & Co., 10 Bridge St.; res., 566a Quincy St., Brooklyn, N. Y. Mar. 25, 1904

FREDEN, FILIP, Nykroppa, Sweden. Mar. 24, 1905

FREELOVE, JAMES LEONARD, Electrician, Malden Electric Co.; res., 9 Benner Ave., Malden, Mass. May 14, 1906

FREEMAN, CLARENCE E. [*Local Secretary*], Prof. of Electrical Engineering, Armour Institute of Technology, Chicago, Ill. Mar. 27, 1903

FREEMAN, WELDON WINANS, Vice-president and Treasurer, Edison Electric Illuminating Co., 360 Pearl St., Brooklyn, N. Y. Apr. 27, 1906

FREIMARK, MAX, Electrical Engineer, Bell Telephone Co. of Philadelphia; res., 1536 N. Darien St., Philadelphia, Pa. Jan. 29, 1904

FRENCH, EDWARD VINTON, Special Inspector, Associated Factory, Mutual Fire Insurance Cos., 31 Milk St., Boston, Mass. July 19, 1904

FRENCH, THOMAS, JR., *Ph.D.*, 40 Brantford Pl., Buffalo, N. Y. Sept. 20, 1893

FRENELL, PER, Electrical Engineer, Elektriska Pronfirgsanstalter, Kungsholmsgatan 8 IV, Stockholm, Sweden. Mar. 29, 1907

FRESTON, CECIL COKE, General Manager, Empresa de Alumbrado Electrico y Fuerza Motriz de Tampico, Tampico, Mex. Feb. 24, 1905

FREUDENBERGER, LEWIS ALFRED, Instructor, Delaware College, Newark, Del. Nov. 20, 1903

FREUDENBERGER, WILLIAM KAISER, Electrical Engineer, Tennessee Copper Co., Copperhill, Tenn. Nov. 22, 1901

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FREUND, HENRY PAUL, 796 Lexington Ave., New York City, Sept. 26, 1902

FREUND, MORTIMER, Laboratorian, Yards and Docks Department U. S. Navy Yard; New York City. July 26, 1907

FREUND, SIEGFRIED, GEORGE, with L. B. Stillwell, 100 Broadway, New York City. Nov. 25, 1904

FREW, JOHN REMINGTON, Engineer, Mexican Light & Power Co., Mecaxa, Puebla, Mex. Nov. 23, 1906

FRIDENBERG, HENRY LESLIE, Nevada Smelting & Mines Corporation, 25 Broad St., New York City. May 17, 1904

FRIEDLANDER, EUGENE, *M.M.* Superintendent Electrical Department, Carnegie Steel Co., Braddock, Pa. Nov. 20, 1895

FRIEDMANN, LOUIS, Electrical Engineer, General Incandescent Arc Light Co.; res., 4131 Calumet Ave., Chicago, Ill. Apr. 28, 1905

FRIEDRICH, OSCAR, Draughtsman, New York Edison Co., 57 Duane St.; res., 14 W. 120th St., New York City. Sept. 28, 1906

FRIES, JÖNS ELIAS Commercial Engineer, Canadian General Electric Co., Toronto, Ont. May 17, 1904

FRITCHLE, OLIVER PARKER, Electrochemist, 1449 Clarkson St., Denver, Colo. Mar. 27, 1903

FROMHOLZ, ANTON JOHN, Electrician in charge, U. S. Navy Yard; res., 71 Linden St., Brooklyn, N. Y. May 20, 1902

FROST, HOMER ELI, Electric Controller & Supply Co., Cleveland, O. Jan. 23, 1903

FRY, AUGUST J., Arnold Co., 181 La Salle St.; res., 182 Oak St., Chicago, Ill. Dec. 28, 1906

FRY, DONALD HUME, Consulting Engineer, Stanislaus Electric Power Co., 909 Kohl Building, San Francisco, Cal. Nov. 23, 1898

FUCHS. HUGO, Electrical Engineering Department, N. Y. C. & H. R. R.R.; res., 208 W. 112th St., New York City. Oct. 23, 1903

FUJIOKA, ICHISUKE Consulting Engineer, Tokyo Street Railway Co.; res., 56 Zaimokucho Azubu, Tokyo, Japan. Sept. 28, 1906

FULLER, ARTHUR JOHN, Borough Electrical Engineer, Corporation Electric Works, Townmead Rd., Fulham, S. W., England. Feb. 27, 1903

FULLER, EDWIN ERNEST, Engineer, British Thomson-Houston Co., 83 Cannon St., London, E. C., Eng. Feb. 28, 1902

FULLER, GEORGE ARTHUR, Superintendent, Edison Electric Illuminating Co. of Boston, 83 Newbury St., Boston, Mass. June 14, 1905

FULLER, HARRY WILLIAMS, General Manager, Washington Ry. & Electric Co., 14th and E. Capitol Sts., Washington, D. C. June 19, 1903

FULLER, HENRY JAMES, Manager and Engineer, John Fowler & Co.; res., 13 Park View, Geeston Hill, Leeds, Eng. Apr. 23, 1903

FULLER, LUCIUS B., Telluride Power Co., Grace, Idaho. Sept. 25, 1903

FULLER, WALLACE WATT, Electrical Engineer, Consolidated Railway Gas and Electric Co., Charleston, S. C. Mar. 27, 1903

FULLERTON, HUGH LEE, Assistant to Electrical Engineer, Allegheny County Light Co., Pittsburg, Pa. Mar. 29, 1907

FULLERTON, RUTHERFORD, Chief Electrician, Scioto Valley Traction Co., 131 E. State St., Columbus, O. Oct. 27, 1905

FULTON, WILLIS STOORS, Laboratory Foreman, Western Electric Co., 463 West St., New York City. Nov. 24, 1905

FUNK, NEVIN ELWELL, Instructor Electrical Engineering, Georgia School of Technology; res., 15 W. 3d St., Atlanta, Ga. June 21, 1907

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FURGUESON, CORNELIUS, JR., Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Mar. 27, 1903

FUSSELL, LEWIS, Assistant in Electrical Engineering, University of Wisconsin; res., 202 Park St., Madison, Wis. Dec. 28, 1906

GABAY, HARRY RUTHERFORD, Underground Engineer, New York Telephone Co. 15 Dey St.; New York City. June 21, 1907

GABOURY, JOHN DOLAN, General Manager, Alabama City, Gadsen and Atlanta Railway Co., Gadsen, Ala. June 21, 1907

GABRIEL, GEORGE ANDREW, Chemical Engineer, 383 E. 18th St., Brooklyn, N. Y. Mar. 25, 1904

GABY, FREDERICK ARTHUR, Asst. Engineer, Hydro Electric Power Commission of Ontario., Toronto, Ont. Nov. 23, 1906

GAENSSLEN, CARL A., 584 La Salle Ave., Chicago, Ill. Apr. 27, 1906

GAGE, ELBERT ELLSWORTH, Superintendent, St. Johnsbury Electric Co., St. Johnsbury, Vt. Apr. 23, 1903

GAIENNIE, FRANK, JR., Electrical Engineer, Oaxaca, Mex. Feb. 26, 1904

GAIENNIE, LOUIS RENE, Superintendent, Kinloch Telephone Co.; res., 4561 McPherson Ave., St. Louis, Mo. Nov. 25, 1904

GAILLARD, LAWRENCE LEE, Electrical Engineer. Consolidated Railway Co., New Haven, Conn. June 15, 1904

GAINES, CLARENCE AUSTIN, Construction Department, California Gas & Electric Co., John Adams, Cal. Mar. 25, 1904

GALE, FRANK HARVEY, Advertising Manager, General Electric Co., Schenectady, N. Y. May 17, 1904

GALLAGHER, EDWARD GERALD, Electrical Engineer, Lake Torpedo Boat Co., Universitatstrasse 3b, Berlin, Germany. May 14, 1906

GALLAGHER, LAURENCE J., Science Department, Wadleigh High School, New York City; res., 147 First St., Troy, N. Y. Sept. 28, 1906

GALLAHER, WILLIAM, Superintendent Electrical Dept., Laclede Gas Light Co., 716 Locust St., St. Louis, Mo. Dec. 18, 1903

GALLATIN, ALBERT R., Schmidt & Gallatin, 111 Broadway, New York City. Mar. 23, 1898

GALLUP, MILTON PALMER, Engineering Department, Providence Tel. Co., Providence, R. I. Sept. 28, 1906

GALUSHA, DON LOOMIS, Electrical Engineer, Stone & Webster Eng'g Corp., 84 State St., Boston, Mass. Oct. 27, 1905

GANGL, FRANCIS, Draftsman, Ford, Bacon & Davis, Birmingham, Ala. Mar. 29, 1907

GAPEN, JOTHAM CLARK, Electrical Inspector, North Shore Electric Co., 114 Oak Park Ave., Oak Park, Ill. Mar. 29, 1907

GARDINER, FREDERICK W., Principal Assistant Engineer, Interborough Rapid Transit Co., 32 Park Pl., New York City. Mar. 29, 1907

GARDNER, CHARLES FRANCIS, Electrical Engineer, Malden Electric Co., Malden, Mass. Oct. 26, 1906

GARDNER, FREDERICK F., General Manager, Seabright Electric Light Co., Red Bank, N. J. Jan. 29, 1904

GARDNER, STEPHEN, Westinghouse Electric and Mfg. Co., 171 La Salle St., Chicago, Ill. Apr. 23, 1903

GARDNER, THOMAS MOONEY, Assistant Professor of Electrical Engineering, University of Illinois, Urbana, Ill. Feb. 23, 1906

GARLAND, CLAUDE M., Instructor in Mechanical Engineering, University of Illinois, Champaign, Ill. Mar. 24, 1905

GARNETT, WILLIAM JAMES, Electrician of the Artillery, U. S. Engineer Dept.; res., 6 Elliott Pl.. Newport, R. I. Mar. 25, 1904

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GARRISON, RALPH HOWARD, Superintendent, Union Railway Supply Co., Philadelphia, Pa. Mar. 1, 1907

GARRARD, CHARLES CORNFIELD, Engineer, Ferranti Ltd., Hollinwood, Lancashire, Eng Sept. 28, 1906

GARRATT, GRAHAM LESIE, Tester, Thomson Houston General Electric Co.; res., 24 Chase St., Lynn, Mass. Mar. 1, 1907

GARRELS, W. L., Consulting Engineer, 1707 South 3d St.; res., 4531 West Pine Boulevard, St. Louis, Mo. Mar. 20, 1895

GARTLEY, ALONZO, General Manager, Hawaiian Electric Co., Honolulu, H. I. July 12, 1900

GARTON, WILLIAM R., President and Treasurer, W. R. Garton Co., 118 West Jackson Blvd., Chicago, Ill. Apr. 28, 1905

GARWOOD, HOMER DEWITT, Assistant Engineer and Draftsmar, Westinghouse, Church, Kerr & Co., Boulder, Colo. Apr. 26, 1907

GARZA, ALDAPE JOSE MARIA, Torreon, Coahuila, Mexico. Aug. 17, 1904

GASSMANN, HOWARD MAIN, Assistant Engineer, Crocker-Wheeler Co., Ampere; res., Newark, N. J. July 28, 1903

GASTON, RALPH MAYO, Electrical Engineer, George P. Nichols & Bro., 927 Monadnock Building, Chicago, Ill. July 28, 1903

GATES, SAMUEL ELVERTON, Testing Department, General Electric Co.; res., 1022 State St., Schenectady, N. Y. Sept. 28, 1906

GATES, WILLIAM FRANKLIN, Tester, General Electric Co., Schenectady, N. Y. Jan. 25, 1907

GAY, FRAZER WALKER, Electrical Engineer, Crocker-Wheeler Co., Ampere, N. J. June 21, 1907

GAY, FREDERICK WALDO, Mechanical Engineer, J. G. White and Co., 43 Exchange Pl., New York City. Apr. 26, 1907

GAYLORD, JAMES MASON, 146 Terrace Drive, Pasadena, Cal. Mar. 29, 1907

GAYLORD, TRUMAN PENFIELD, 171 La Salle St., Chicago, Ill. Feb. 28, 1902

GAYTES, HERBERT, Electrical Engineer, Oakland, Cal. Mar. 23, 1898

GEAR, HARRY BARNES, General Inspector, Chicago Edison Co., 139 Adams St., Chicago, Ill. Oct. 25, 1901

GEARY, JOHN RICHARD, Rrepesentative for Japan, General Electric Co.; res., Yokohama United Club, Yokohama, Japan. Mar. 27, 1903

GEIB, ADAM, Rue de St. Felix, Far Rockaway, N. Y. July 19, 1904

GENTIS, ERNEST L., Electrical Draftsman, Newport News Shipbuilding & Dry Dock Co., Newport News, Va. June 14, 1905

GERDES, THEODORE RICHARD NICKOLAS, Rodman, Rapid Transit Construction Co.; res., 5 Van Nest Pl., New York City. Feb. 27, 1903

GERHARDT, PHILIPP WILHELM, Testing Department, General Electric Co.; res. 905 State St., Schenectady, N.Y. June 21, 1907

GERRY, EDWARD M., Engineer, Bullock Electric Mfg. Co., Cincinnati' Ohio. Mar. 27, 1903

GIBBES, THOMAS, MIDDLETON, Contract Department, Minneapolis General Electric Co., Minneapolis, Minn. Sept. 25, 1903

GIBBONEY, WILLIAM KENT, Massena, N. Y. Sept. 27, 1901

GIBBS, GEORGE SLOCOMB, Sales Engineer, Westinghouse E. & M. Co., 716 Board of Trade Building, Boston, Mass. June 15, 1904

GIBBS, HARRY THURSTON, Brooklyn Heights R. R. Co., 39th St. Shops, Brooklyn, N. Y. June 19, 1903

GIBSON, GEO. H., Advertising Engineer, 716 Tribune Bldg., New York City. Nov. 22, 1899

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GIBSON, JOHN JAMESON, Sales Westinghouse E. & Mfg. Co., Land Title Bldg. Philadelphia, Pa. Feb. 28, 1902

GIERISCH, OTTO TOMAS, Draughtsman, Brooklyn Heights R. R. Co., 85 Clinton St., Brooklyn, N.Y. Jan. 25, 1907

GIFFIN, FRANK ALBEE, Engineer, W. E. Baker. 27 William St., New York City. Apr. 22, 1904

GILBERT, CHARLES HENRY, [*Local Secretary*], Worcester Polytechnic Institute, Worcester, Mass. Mar. 25, 1904

GILBERT, E. E., General Electric Co., Schenectady, N. Y. Apr. 23, 1903

GILBERT, HAROLD ADDINSELL, Draftsman, Kinsman Block System Co.; 55 Dey St., New York City. Mar. 1, 1907

GILBERT, HENRY CURTIS, JR., Department of Electricity, Jamestown Exposition Co., Pine Beach, Va. Jan. 25, 1907

GILBERT, HOWARD LUDLOW, 2227 Madison Ave., Baltimore, Md. May 19, 1903

GILBERT, JOSEPH N., Chief Engineer, National Construction and Equipment Co., Norwich, Conn. June 21, 1907

GILBERT, SWOOPE DARROW, Commercial Engineer, General Electric Co., Cincinnati, Ohio. June 19, 1903

GILCHREST, CHARLES CHANDLER, Telephone Engineer, Western Electric Co., 463 West St., New York City. Dec. 15, 1905

GILCHRIST, EDWARD L., Engineer, Potomac Electric Power Co., Washington, D. C. Apr. 26, 1907

GILCHRIST, JOHN FOSTER, Head Contracting Dept., The Chicago Edison Co., 139 Adams St., Chicago, Ill. Jan. 23, 1903

GILCREST, CHARLES F., 1424 Linden St., Oakland, Cal. Sept. 25, 1903

GILDER, RODMAN, Publicity Manager, Crocker-Wheeler Co., Ampere, N. J.; res., 13 E. 8th St., New York City. June 14, 1905

GILL, CLYDE ROSS, Superintendent Electrical Distribution Sacramento Electric Gas and Railway Co., Sacramento, Cal. June 21, 1907

GILL, FRANK, Engineer in Chief, The National Telephone Co., Ltd., Telephone House, Victoria Embankment, London, E. C. May 19, 1903

GILL, LESTER WILLIS, Professor, School of Mining, Kingston, Ont. Mar. 24, 1905

GILLE, HENRY JOHN, General Superintendent, St. Paul Gas Light Co., St. Paul, Minn. Jan. 25, 1901

GILLET, LOUIS ALLSTON, *M.E.*, Fishkill-on-Hudson; res., 32 W. 10th St., New York City. Apr. 22, 1904

GILLIAM, HOGE, Erecting Engineer, W. E. & Mfg. Co., Pittsburg, Pa Jan. 23, 1903

GILLILAND CLARENCE REY, Ry. and Ltg Dept., Westinghouse E. & M. Co., 341 W. Main St., Louisville, Ky. May 17, 1904

GILMAN, RALPH EDSON, Engineer, The British Westinghouse E. & M. Co., Ltd., Manchester, Eng. Sept. 25, 1903

GILMORE, ALBERT DICKISON, Superintendent of Tests, Electrical Power, N. Y. C. R. R., New York City. Mar. 27, 1903

GINN, EVANDER H., Railway Engineering Department, General Electric Co., Empire Building, Atlanta, Ga. Mar. 27, 1903

GIRDWOOD, KENNET J., Electrical and Mechanical Engineer, "Comparia Minera Las Dos Estrellas," El Oro, Mexico. Nov. 23, 1906

GLASGOW, CARR LANE, Engineer, Westinghouse, Church, Kerr & Co., 8 Bridge St.; res., 164 W. 50th St., New York City. Mar. 27, 1903

GLASSCO, JOHN GIRDLESTONE, Hamilton Cataract Power, Light & Traction Co., Ltd., Hamilton, Ont. May 19, 1903

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GLENCK, IMMO ADOLPH HEINRICH, Consulting Engineer, for Electricity and Gas Production, Frankfurt A/M, Germany. Jan. 23, 1903

GLENN, CHARLES SEWALL, Electrical Inspector, Solvay Process Co., Syracuse, N. Y. May 17, 1904

GLENN, THOMAS KNOX, General Electric Co., Empire Building, Atlanta Ga. May 14, 1906

GLENN, WILLIAM HARPER, Superintendent Roadways, Georgia Ry. & Electric Co., 24 E. Alabama St., Atlanta, Ga. June 15, 1904

GLOVER, BENJAMIN HOWELL, Supt. M. P., Metropolitan West Side Elevated Ry. Co., 1001 Royal Ins. Bldg., Chicago, Ill. Jan. 29, 1904,

GOBEL, FRANK CONANT, Electrician, Arbuckle Bros., foot of Jay St.; res., 44 Fort Greene Pl., Brooklyn, N. Y. Nov. 24, 1905

GODDARD, STEPHEN HAILE, Secretary and Manager, *Electrical Review*, 13 Park Row; res., 223 Fifth Ave., New York City. Sept. 25, 1903

GODDARD, WALTER THOMPSON, Electrical Engineer, Locke Insulator Mfg. Co., Victor, N. Y. Oct. 28, 1904

GOEHST, J. HENRY, Construction Superintendent, Chicago Edison Co., 139 Adams St.; res., 4613 Langley Ave., Chicago, Ill. May 17, 1904

GOEPEL, CARL PAUL, Counsellor-at-Law, Goepel and Goepel, 290 Broadway, New York City. Mar. 24, 1905

GOETTLING, GERHARD MAX WILLY, Electrical Engineer, Edison Electric Illuminating Co., 516 Atlantic Ave., Boston. Nov. 25, 1904

GOFFIN, EDWARD WILLIAM, Commercial Work, General Electric Co., 84 State St., Boston; res., Lynn, Mass. Nov. 23, 1906

GOGGANS, DANIEL FORREST, J. M. O'Rourke & Co., Roosevelt, Ariz. Aug. 25, 1905

GOLDIE, MATTHEW McLEAN, McGill University, Montreal, Que. Dec. 15, 1905

GOLDING, HENRY JOHN, Electrical Engineer, Elliott Bros., Lewisham, London, S. E., Eng. Feb. 24, 1905

GOLDMAN, GEORGE, Engineer, General Electric Co.; res., 9 Grove Pl., Schenectady, N. Y. Mar. 25, 1904

GOLDMARK, CHAS. J., Consulting Electrical Engineer, 7 W. 38th St., New York City. June 5, 1888

GOLDRICK, HARRY C., Kellogg Switchboard and Supply Co., 404 Ashdown Building, Winnipeg, Manitoba. Sept. 22, 1905

GOLDSCHMIDT, EDWARD W., District Sales Agent, Wagner Electric Mfg. Co., 17 Battery Pl., New York City. July 28, 1903

GOLDSMITH, LEON, Westinghouse E. & M. Co., 11 Pine St., New York City. May 17, 1904

GOODELL, JOHN M., *Engineering Record*, 239 W. 39th St., New York City. Feb. 27, 1903

GOODING, HENRY L., Electrician in charge, Department of Ordnance, Brooklyn Navy Yard, N. Y. Mar. 29, 1907

GOODWILLIE, ROBERT HOGUE, Electrical Engineer, Otis Elevator Co., Yonkers, N. Y., Mar. 25, 1904

GOODWIN, WILLIAM NELSON, JR., Chief Electrical Engineer, Weston Electrical Instrument Co., Waverly Park, N. J. Sept. 28, 1906

GOODY, CORAL PAYNE, Assistant Engineer, The Telluride Power Co., Provo, Utah. Oct. 24, 1902

GORDON, GEORGE BYRON, Wire Chief, Chesapeake & Potomac Tel. Co., Washington, D. C. May 19, 1903

GORDON, JAMES RUTHERFORD, District Manager, Westinghouse Electric and Mfg. Co., Candler Building, Atlanta, Ga. Mar. 1, 1907

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GORDON, REGINALD, Newburg, N. Y. Feb. 24, 1891

GORMAN, HARRY B. L., Tester, Northern Electrical Mfg. Co., res.; 214 Buell St., Madison, Wis. Jan. 27, 1905

GORRISSEN, CH., Siemens Bros. & Co., Ltd., York Mansions, York St., Westminster, London, S. W., Eng. Mar. 25, 1896

GORSUCH, WILLIAM SCHROFIELD, Assistant Electrical Engineer, N. Y. C. & H. R. R.R. Co., New York City. Mar. 29, 1907

GOSLIN, ERNEST THOMAS, Chief Electrical Engineer, Corporation Tramways, 46 Bath St., Glasgow, Scotland. May 19, 1903

GOSS, HOWARD DANA, Tester, Western Electric Co., res.; 1536 Ogden Ave., Chicago, Ill. Sept. 28, 1906

GOTTLIEB, PAUL, Electrical Engineer, 677 Golden Gate Ave., San Francisco, Cal. Aug. 25, 1905

GOUGH, CALE ROBERT, Editorial Staff, Street Railway Journal, 1139 Monadnock Building, Chicago, Ill. Dec. 28, 1906

GOUGH, EDGAR W., Engineer, J. G. White & Co., Pottsville, N. Y. Feb. 26, 1904

GOUGH, HARRY EUGENE, Assistant in Office Mechanical Engineers, Penn. R. R. Co., res.; 2406 Maple Ave., Altoona, Pa. Jan. 9, 1901

GOULD, CHARLES M., Treasurer, Gould Storage Battery Co., 341 Fifth Ave., New York City; res., Bayside, L. I. Jan. 29, 1904

GOULD, EDWARD FREDERICK, Electrical Engineer, Aurora, Elgin & Chicago Railway Co., Wheaton, Ill. Sept. 25, 1903

GOULD, THEODON, JR., Electrician, Electric Engineering Dept., Public Buildings; res., 17 Wigglesworth St., Boston, Mass. Jan. 26, 1906

GOULD, WILLIAM S., Vice-president and General Manager, Gould Storage Battery Co., 341 Fifth Ave., New York City. Jan. 29, 1904

GRACE, SERGIUS P., Chief Engineer, Central District and Printing Telegraph Co., Pittsburg, Pa. Mar. 27, 1903

GRADOLPH, WILLIAM FREDERICK, JR., Chief Engineer, American Electric Co., 806½ Chestnut St., St. Louis, Mo. Jan. 23, 1903

GRAHAM, FRANK WALDRON, Superintendent of Construction, Department of Electricity, Jamestown Exposition, Norfolk, Va. Apr. 26, 1907

GRAHAM, WILLIAM P., Professor of Electrical Engineering, Syracuse University, Syracuse, N. Y. Jan. 24, 1902

GRALING, VERNEY, Electrician, Niagara Falls Power Co.; res., 1104 Ferry Ave., Niagara Falls, N. Y. Aug. 22, 1902

GRANBERY, JULIAN H., J. G. White & Co., 43 Exchange Pl., New York City. Aug. 5, 1896

GRANT, LOUIS T., Consulting Engineer, 68 Dulumbayan, Manila, P. I. Nov. 22, 1899

GRANT, OLIVER REMICK, Asst. to Electrical Engineer, Safety Insulated Wire & Cable Co., Bayonne, N. J. Mar. 28, 1902

GRANT, WILLIAM WRIGHT, Manager, American Conduit Co., 140 Nassau St., New York City; res., Englewood, N. J. June 21, 1907

GRAUTEN, SYLVESTER HENRY, Assistant, Massachusetts Institute of Technology; res., 9 St. James Ave., Boston, Mass. Sept. 28, 1906

GRAVES, CARLETON AUGUSTUS, Electrical Engineer, Edison Building, Pearl St., Brooklyn. Mar. 27, 1903

GRAVES, GEORGE HARRISON, Mechanical and Electrical Engineer, U. S. Treasury Dept., New York City. Jan. 29, 1904

GRAY, AINSLIE ALEXANDER, Assistant Editor, *Electrical Review*, 13 Park Row, New York City. Aug. 22, 1902

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GRAY, ALEXANDER MILLER, Engineering Officer, Bullock Electric Mfg. Co., Cincinnati, O. Sept. 28, 1906

GRAY, CHARLES FREDERICK, Superintendent of Construction, Canadian Westinghouse Co., Hamilton, Ont. Dec. 19, 1902

GRAY, CLYDE D., Assistant in Electrical Department, J. G. White & Co., 43 Exchange Pl., New York City. Apr. 25, 1902

GRAY, EDWARD WYLLYS TAYLOR, Continental Insurance Co., 46 Cedar St., New York City. Jan. 3, 1902

GRAY, GEORGE EVERARD, Gray Electric Co., Leavenworth, Kan. Feb. 24, 1905

GRAY, LATIMER D., Electrical Engineer, Union Pacific Coal Co., Rock Springs, Wyo. Feb. 27, 1903

GRAY, MAURICE LELAND, Engineering Department, Union Switch and Signal Co., Swissvale, Pa. Sept. 28, 1906

GRAY, OWEN HERRICK, Consulting Electrical Engineer, 320 Dooly Block, Salt Lake City, Utah. May 14, 1906

GRAY, PERCY, 76 W. 131st St., New York City. Feb. 23, 1906

GRAY, ROY WILLIAM, Engineering Dept., Pacific Telephone & Telegraph Co., Portland, Ore. Nov. 20, 1903

GRAY, VANCE I., Engineer and Salesman, The F. Bissell Co., Toledo, O. Feb. 27, 1903

GREEN, ALFRED, Brooklyn Heights R. R., 168 Montague St.; res., 111 Columbia Heights, Brooklyn, N. Y. May 15, 1905

GREEN, CHARLES MAXWELL, Engineer on Brush Arc Dynamos, General Electric Co., 94 Beacon Hill Ave., Lynn, Mass. Feb. 28, 1902

GREEN, FRED. J., Electrical and Mechanical Engineer, Springfield Troy & Piqua Railway Co., Bushnell Bldg., Springfield, O. Apr. 23, 1903

GREEN, GEORGE ROSS, Engineering Dept., Philadelphia Electric Co., 10th and Chestnut Sts., Philadelphia, Pa. Apr. 23, 1903

GREEN, HEATLEY, Massnick Mfg. Co., 1567 River St.; res., 42 Woodland Terrace, Detroit, Mich. Dec. 18, 1903

GREENE, FRANCIS VINTON, Vice-President, Ontario Power Co., Fidelity Building, Buffalo, N. Y. June 21, 1907

GREENE, GEORGE DE BOKETON, Engineering Expert, E. H. Rollins and Sons, 19 Milk St., Boston, Mass. May 14, 1906

GREENLEAF, LEWIS STONE, General Superintendent, Hudson River Telephone Co., Albany, N. Y. Aug. 5, 1896

GREGORY, JOHN PUGH, Engineer, Power and Lighting Department, The British Thomson-Houston Co., Ltd., Rugby, Eng. Sept. 25, 1903

GRESHAM, WILLIAM ANDREW, Chief Dynamo Man, Georgia Electric Co.; res., 474 So. Pryor St., Atlanta, Ga. Apr. 22, 1904

GREVATT, FRANK FROMMEL, Electrical Engineer, Crocker-Wheeler Co., Ampere; res., 291 Spring St., W. Hoboken, N. J. May 15, 1905

GREY, LEWIS VALENTINE, Operator, Baker Light and Power Co., Baker City; res., Haines, Ore. Dec. 15, 1905

GRIER, ARTHUR GORDON, Engineer, Wescott & Grier, Merchants' Bank Building, Montreal Que. July 19, 1904

GRIFFEN, JOHN D., Inventor, Electric Conduit and Electric Signaling Apparatus, 82 Wall St., New York City. Aug. 13, 1897

GRIFFES, EUGENE V., Oceanside Electric & Gas Co., Oceanside, Cal. Feb. 26, 1896

GRIFFIN, THOMAS LLOYD, Agent, General Electric Co., Wilkesbarre, Pa. Apr. 22, 1904

GRIFFITH, PERCY LE ROY, Electrical Engineer, New York Telephone Co., 18 Cortlandt St., New York City. Dec. 19, 1902

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GRISSINGER, ELWOOD, Engineer, The Cataract Power & Conduit Co., 718 Fidelity Building, Buffalo, N. Y. Mar. 28, 1902

GROSVENOR, GRAHAM B., Otis Elevator Co., 17 Battery Pl.; res., 126 W. 12th St., New York City. Jan. 25, 1907

GROVE, EDMUND PHILIP, Chief Engineer, Central London Railway, Caxton Road, Shepherd's Bush, London W., Eng. Mar. 24, 1905

GROVER, WILLIAM HARLEY, Superintendent of Fires, Light and Power, Iowa State College, Ames, Iowa. Mar. 1, 1907

GUDEMAN, LEO, 170 E. 93d St., New York City. Feb. 26, 1904

GUERRERO, JULIO, Associated with the Durango Electric Light Co., Reresas, 97 Durango, Mex. Apr. 25, 1900

GUGLER, J. H., President, Gugler Electric Mfg. Co., 223 5th St. South; res., 2624 Garfield Ave., Minneapolis, Minn. Aug. 25, 1905

GUINLE, EDWARD, Electrical Engineer, 55 Rua do Ouvidor, Rio de Janeiro, Brazil. Mar. 27, 1903

GUIRKIN, CHARLES, Vice-president and General Manager, Elizabeth City Telephone Co., Elizabeth City, N. C. Nov. 24, 1905

GULICK, RAY ALEXANDER, Assistant to Chief Engineer C. H. Holley, Mount Whitney Power Co., Visalia, Cla. June 21, 1907

GULICK, RAYMOND W., Electrical Draftsman, U. S. Navy Yard; res., 44 Fort Greene Pl., Brooklyn, N. Y. Jan. 25, 1907

GUMP, WALTER BINKERD, Electrical and Mechanical Engineer, 2510 Juliet Ave., Los Angeles, Cal. Nov. 20, 1903

GUNN, ROBERT T., General Manager, Lexington Railway Co., Lexington, Ky. Feb. 23, 1906

GUNTER, EMIL, Chief Engineer, Winnebago Traction Co., Oshkosh, Wis. Feb. 23, 1906

GUTBROD, FRIEDRICH WILHELM, Engineer, Attaché to German Embassy, 11 Broadway, New York City. Feb. 27, 1903

GUY, GEORGE HELI, Secretary, The New York Electrical Society, 29 W. 39th St., New York City. May 16, 1893

HAAR, SELBY, Engineer, General Electric Co.; res., 201 Victory Ave., Schenectady, N. Y. June 21, 1907

HAAS, HENRY CHARLES, Operating Department, Electric Storage Battery Co., 100 Broadway, New York City. Mar. 23, 1906

HABERLY, JAMES HAGER, Salesman, Fort Wayne Electric Works, Fort Wayne, Ind. Apr. 27, 1906

HACKETT, CHARLES MARCUS, Electrical Engineer, N. Y. C. & H. R. R. R.; res., 137 Washington St., Mt. Vernon, N. Y. Feb. 23, 1906

HADDOCK, MORTON WEBSTER, Supervisor of Maintenance, N. E. Telephone and Telegraph Co., 119 Milk St., Boston, Mass. Mar. 29, 1907

HAIGHT, LOUIS HENRY, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City. May 19, 1903

HAIGHT, MONROE GLEASON, Westchester Lighting Co., Mt. Vernon, N. Y. July 25, 1902

HAIGLER, WILLIAM HOPE, Partner, Mosley-Haigler Electric Co., 216 Bibb St., Montgomery, Ala. June 19, 1903

HAINES, EDWARD L., Electrical Engineer, J. G. White & Co., 43 Exchange Pl.; res., 158 W. 46th St., New York City. Feb. 23, 1906

HAISLIP, R. A., Telephone Engineer, 204 Sherwood Ave., Staunton, Va. Apr. 26, 1907

HAGGERTY, HENRY DAVID, Assistant Foreman of Station Construction, New York Edison Co., New York City. Sept. 28, 1906

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HAKONSON, CARL HARALD, Electrical Engineer, Allmanna Svenska E. A. B., Westeras, Sweden. Sept. 25, 1895

HALCOMBE, WALTER PEARCE, Engineer and Salesman, Frank Adam Electric Co.; res., 5700 Bartmer Ave., St. Louis, Mo. Sept. 28, 1906

HALDY, FREDERICK GEORGE, Yale and Towne Mfg. Co., Stamford; res. Glenbrook, Conn. June 21, 1907

HALE, ROBERT SEVER, Assistant to Gen. Supt., Edison Electric Ill. Co. of Boston, 925 Boylston St., Boston, Mass. Aug. 25, 1905

HALE, WILLIAM BUELL [*Local Hon. Secretary*], Gen. Mgr., Mexican Tel. & Tel. Co., Arco de San Agustin 8, City of Mexico. Apr. 22, 1904

HALL, CLARENCE MORTIMER, Teacher of Physics and Electricity, Manual Training School No. 1, Washington, D. C. Mar. 28, 1902

HALL, DAVID, Assistant Chief Engineer, Bullock Electric Mfg. Co., Cincinnati, O. Mar. 27, 1903

HALL, EDWARD J., Vice-president and G. M., American Telephone and Telegraph Co., 15 Dey St., New York City. Apr. 18, 1893

HALL, EDWIN CHAMBERLAYNE, Manager, Gray National Telautograph Co.; res., 317 North Craig St., Pittsburg, Pa. Jan. 25, 1907

HALL, FREDERICK A., Ingersoll-Rand Co., 11 Broadway, New York City. Aug. 23, 1899

HALL, FREDERICK JAMES, Assist. to General Manager, The India Rubber and Gutta Percha Insulating Co., Yonkers, N. Y. May 19, 1903

HALL, GAYLORD CROSETTE, Electrical Superintendent, Interborough Rapid Transit Co., New York City. Mar. 1, 1907

HALL, GEORGE RAYMOND, Assistant Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. Apr. 26, 1907

HALL, HARRIOTT CURTIS, Testing Department, General Electric Co.; res., 602 Union St., Schenectady, N. Y. June 28, 1901

HALL, HARRY YOUNG, JR., Assistant Electrical Engineer, Southern Pacific Co., 1110 Flood Bldg., San Francisco, Cal. Mar. 27, 1903

HALL, JAY HOUGHTON, Sales Engineer, Electric Controller and Supply Co.; res., 350 Genesee Ave., Cleveland. O. Jan. 27, 1905

HALLBERG, J. H., Consulting Engineer, 30 Greenwich Ave., New York City. Aug. 23 1899

HALLER, WINFIELD A., Engineer, Sanderson & Porter, 52 William St., New York City. Sept. 25, 1903

HALLORAN, HARRY RICHMOND, Townsville, Queensland. May 14, 1906

HALLSWORTH, HERBERT MORTLOCK, Draughtsman, Western Electric Co.; Chicago; res., Riverside, Ill. Jan. 27, 1905

HALSEY, HENRY, General Manager, Halsey Electric Generator Co., 400 Claremont Ave., Jersey City. July 28, 1903

HAMBLIN, MERTON OGILVA, Repairman, Commonwealth Power Co., 620 Grace St., Kalamazoo, Mich. Dec. 28, 1906

HAMBURGER, MAX, *Ph.D.*, Electrical Engineer, Union Electricitats-Gessellschaft; res., 8 Pariser St., Berlin, Ger. July 28, 1903

HAMERSCHLAG, ARTHUR A., Director, Carnegie Technical Schools, 313 Sixth Ave., Pittsburg, Pa. Mar. 25, 1896

HAMILTON, GEORGE WELLINGTON, Assistant Engineer, Consolidated Ry.; res., 494 Howard Ave., New Haven, Conn. Jan. 23, 1903

HAMILTON, HUGH DE COURSEY, Sales Engineer, Crocker-Wheeler Co., 1315 North American Building, Philadelphia. Jan. 25, 1907

HAMILTON, ISAAC, Master Signal Electrician, Signal Corps, U. S. Army, Ft. McHenry, Md. Jan. 27, 1905

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HAMILTON, JAMES, Patent Law Specialist, 31 Nassau St., New York City; res., Lincoln Ave., Orange, N. J. Nov. 23, 1898

HAMILTON, JOHN, Chief Electrician, Boston Elevated Railway Co., 555 Harrison Ave., Boston, Mass. June 14, 1902

HAMILTON, RALPH BERGEN, Manager, The Packard Electric Co., Ltd., St. Catharines, Ont. Nov. 22, 1901

HAMMATT, CLARENCE S., Vice-president Florida Electric Co., Jacksonville, Fla. Sept. 20, 1893

HAMMOND, JOHN WOODS, Superintendent, Light, Water and Sewerage Commission, Griffin, Ga. Oct. 27, 1905

HAMMOND, LYMAN PIERCE, Sales Manager, Denver Engineering Works, Denver, Colo. Mar. 27, 1903

HAMNER, CHARLES SUTHERLAND, Engineer and Contractor, Cuba 58, Havana, Cuba. Dec. 23, 1904

HAMPSON, RICHARD BENJAMIN, Salesman, General Electric Co.; res., 20 Rogers Ave., Lynn, Mass. Apr. 23, 1903

HANCOCK, L. M., Consulting Electrical Engineer, Fortuna Lighting Co., Fortuna, Cal. May 19, 1891

HANCOX, SAMUEL HERBERT, Electrician, Queensland Government Railways, North Ipswich, Queensland, Aus. Sept. 25, 1903

HAND, WILLIAM, Engineer, General Electric Co., 816 Wainwright Building; res., 727 Walton Ave., St. Louis, Mo. Apr. 23, 1903

HANKER, FRED, CHARLES, Designing Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Jan. 27, 1905

HANKS, MARSHALL, WILFRED Engineer, 216 Langdon St., Madison, Wis. Jan. 3, 1902

HANNA, MAX ROSS, Electrical Engineer, General Electric Co., Schenectady, N. Y. Apr. 23, 1903

HANSCOM, PERRY THEODORE, Engineer, Curtis & Hine, Giddings Building, Colorado Springs, Colo. Mar. 27, 1903

HANSCOM, WM. W., Chief Electrical Engineer, Union Iron Works, 848 Clayton St., San Francisco, Cal. Apr. 25, 1900

HANSEN, VIGO, Engineering Department, New York Edison Co., New York City. May 14, 1906

HANSON, ARTHUR JAMES, Lawrence & Hanson, 33 York St.; res., Drummoyne, Sydney, N. S. W. Nov. 22, 1899

HANSSEN, IVAN EIVIND, Electrical Engineer, Stanley G. I. Electric Mfg. Co.; res., 27 Willis St., Pittsfield, Mass. Jan. 25, 1907

HARDER, EDWIN PARTRIDGE, The Cataract Power and Conduit Co.; res., 28 California St., Buffalo, N. Y. Apr. 23, 1903

HARDING, CHARLES FRANCIS, Stone & Webster, 84 State St., Boston, Mass. Jan. 26, 1906

HARDING, H. McL., 20 Broad St., New York City. May 24, 1887

HARDY, CARL ERNEST, Master Electrician, Department construction and repair, Navy Yard, Mare Island. Dec. 27, 1899

HARISBERGER, JOHN, Seattle, Tacoma Power Co., Seattle, Wash. May 20, 1902

HARKNESS, WILLIAM EDWARD, Telephone Engineer, Western Electric Co.; 463 West St., New York City. Sept. 28, 1906

HARLEY, EDWARD A., Operating Superintendent. 3d District, New York Edison Co., 173 W. 107th St., New York City. Mar. 23, 1906

HARLOW, GEORGE, British Westinghouse Electrical and Mfg. Co., Ltd., Ashwood, Timperley, Cheshire, Eng. Mar. 1, 1907

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HARPER, HERBERT REAH, City Electrical Engineer, Melbourne City Council, Town Hall, Melbourne, Victoria. June 19, 1903

HARPER, WALTER ANDREW, Consulting Engineer, Harper Brothers & Co.; res., 13 St. Helen's Pl., E. C., London, Eng. Feb. 23, 1906

HARRIES, GEORGE HERBERT, Vice-president, The Washington Railway and Electric Co., Washington, D. C. June 19, 1903

HARRINGTON, ALFRED LEWIS, Erecting Engineer, General Electric Co., 1508 Park Building, Pittsburg, Pa. June. 21, 1907

HARRIS, CHARLES ORRIN, Engineer, Utah Independent Telephone Co., Salt Lake City, Utah. Sept. 25, 1903

HARRIS, FORD WHITMAN, Engineer, Westinghouse Electric and Mfg. Co.; res., 318 Rebecca St., Wilkinsburg, Pa. Feb. 23, 1906

HARRIS, GEORGE H., Superintendent of Equipment, Birmingham Railway Light and Power Co., Birmingham, Ala. June 20, 1894

HARRIS, EDSON SHEPPARD, Salesman, Dolier Engineering Co., 119 South 11th St., Philadelphia; res. Swarthmore, Pa. June 21, 1907

HARRIS, GRENVILLE A., Electrical and Mechanical Engineer, Takata & Co., 60 Wall St., New York City. Oct. 25, 1901

HARRIS, HENRY CHARLES, Electrical Inspector, Ohio Inspection Bureau, res., 318 East State St., Columbus, O. Apr. 28, 1905

HARRIS, JAMES WILFRID, Engineer, Dominion Iron & Steel Co., Ltd., Sydney, N. S. Can. Oct. 28, 1904

HARRIS, MAX, General Sales Manager, Nernst Lamp Co., Pittsburg; res., 1127 Sheffield St., Allegheny, Pa. Mar. 1, 1907

HARRIS, PHILIP HOWARD, Erecting Engineer, Westinghouse Elec. Mfg. Co., Baltimore, Md. Feb. 23, 1906

HARRIS, SAMUEL CLARK, in charge of Storage Batteries, New York Edison Co., 47 W. 26th St., New York City. May 19, 1903

HARRIS, WILLIAM WOODSON, JR., California Powder Works, Pinole, Cal. Nov. 25, 1904

HARRISON, BURT SYLVANUS, Consulting Engineer, 11 E. 24th St.; res., 442 Lexington Ave., New York City. June 19, 1903

HARRISON, JAMES, Chief Engineer, The Kinloch Telephone Co., Kinloch Building, St. Louis, Mo. Apr. 23, 1903

HARRISON, O. L., Construction Engineer Electric Storage Battery Co., 1400 Association Building, Chicago, Ill. June 21, 1907

HART, A. STUDLEY, Special Solicitor, Putnam Light and Power Co., Industrial Trust Bldg., Providence, R. I. Sept. 28, 1906

HART, HARRY U., Chief Engineer, Canadian Westinghouse Co., 57 Charlton Ave., Hamilton, Ont. June 21, 1907

HART, PERCY E., Electrical Engineer, Canadian General Electric Co., 14 King St. E., Toronto, Ont. Sept. 25, 1903

HART, WALTER SCUDDER, Erecting Engineer, Electric Storage Battery Co., 1400 Association Building, Chicago, Ill. Oct. 26, 1906

HARTER, BRET, 1123 Schofield Building, Cleveland, O. July 26, 1900

HARTMAN, GEORGE, Superintendent of Electric Power House, Hurorian Co., Turbine, Ont. Sept. 28, 1906

HARTMANN, FRANCIS M., Instructor of Experimental Physics and Electrical Measurements, Cooper Union, New York City. Sept. 26, 1902

HARTRATH, ARMIN, with Geo. P. Hutchins, 120 Liberty St.; res., 23 W. 12th St., New York City. Dec. 28, 1906

HARVEY, DEAN, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Mar. 25, 1904

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HARVEY, GILBERT ALEXANDER, Electrical Engineer, International Railway Co., Buffalo, N. Y. May 19, 1903

HARVEY, ROBERT R., 20 So. Franklin St., Wilkesbarre, Pa. [Life Member.] Sept. 25, 1895

HARVIE, WILLIAM JAMES, Electrical Engineer, Utica and Mohawk Valley Ry. Co., Utica, N. Y. Apr. 23, 1903

HASELDEN, HARRY ARIEL, Electrical Engineer, The Whitin Machine Works, Whitinsville, Mass. Oct. 24, 1902

HASELTON, PARKER HARVEY, Salesman, Fort Wayne Electric Works, 615 Germania Life Building, St. Paul, Minn. Sept. 28, 1906

HASHIMOTO, SENNOSUKE, Electrical Engineer, Osaka Electric Light Co., Osaka, Japan. May 15, 1905

HASKELL, GEORGE MYRON, Selling Agent, J. G. Brill Co.; res., 32 Maple St., New Haven, Conn. May 19, 1903

HASKINS, WILLIAM EDGAR, Superintendent, Willimantic Gas and Electric Co., Willimantic, Conn. Jan. 25, 1901

HASSLER, CHAS. T. F., Uplandsgatan 7, Stockholm, Sweden. Oct. 24, 1900

HASTINGS, LOUIS BROUNELL, Erecting Road Engineer, Stanley Electric Mfg. Co., Pittsfield, Mass. Oct. 23, 1903

HATCH, AUSTIN SMITH, Consulting Engineer, Bullock Electric & Mfg. Co., Cincinnati, Ohio. Sept. 26, 1902

HATCH, BENJAMIN BRIGGS, Electrical Engineer, Public Buildings, Boston; res., 11 Sawyer Ave., Dorchester, Mass. Jan. 26, 1906

HATCH, GEORGE ELWYN, 58 Florida Chambers, Ashmont, Mass. Jan. 26, 1906

HATHAWAY, JOSEPH D., JR., Superintendent, The Wire & Cable Co., Montreal, Que. Aug. 5, 1896

HATZEL, J. C., Firm Hatzel & Buehler, 571 Fifth Ave.; res., 1231 Madison Ave., New York City. Sept. 3, 1889

HAUBRICH, ALEX. MICHAEL, Electrical Engineer, Stromberg-Carlson Telephone Mfg. Co., Chicago, Ill. Apr. 26, 1901

HAUSMANN, ERICH, Electrical Testing Laboratories, 556 E. 80th St.; res., 234 E. 42d St., New York City. Jan. 26, 1906

HAWKINS, CHARLES CAESAR, Electrical Engineer, H. Allen, Son & Co., Ltd.; res., 37 Conduit Road, Bedford, Eng. Nov. 20, 1903

HAWKINS, ELBERT ALLEN, Telephone Engineer, Western Electric Co., 463 West St., New York City. Dec. 28, 1906

HAWKINS, LAURENCE A., Engineer, Patent Department, General Electric Co., Schenectady, N. Y. Jan. 23, 1903

HAWKINS, WILLIAM CLARK, General Manager and Secy., Hamilton Cataract Power Lt. Traction Co., Ltd., Hamilton, Ont. June 19, 1903

HAWKS, H. D., Engineer, with General Electric Co., 44 Broad St., New York City. May 21, 1901

HAWXHURST, ROBERT, JR., General Manager, Pcderosa Mining Co., Antcfagasta, Chili, S. A. Sept. 22, 1905

HAYDEN, JOSEPH LE ROY, Electrical Engineer, General Electric Co.; res., Wendell Ave., Schenectady, N. Y. Jan. 29, 1904

HAYDEN, VIRGIL, Electrical Engineer, Frontier Telephone Co.; res., 26 Laurel St., Buffalo, N. Y. Oct. 28, 1904

HAYES, CLIFTON RICHMOND, Electrical Engineer, Ludlow Mfg. Associates, Ludlow, Mass. June 19, 1903

HAYES, JAMES EDWARD, JR., Assistant in Laboratory, Western Electric Co., New York City. Mar. 27, 1903

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HAYES, JOHN BARTLETT, Union Electric Light and Power Co., 3149 Locust St., St. Louis, Mo. June 19, 1903

HAYLER, GEORGE ERNEST, JR., Superintendent Spring River Power Co., 315 Miners' Bank Building, Joplin, Mo. Feb. 23, 1906

HAYLLAR, BENJAMIN, JR., Westinghouse Electric and Mfg. Co.; res., 123 West Washington Lane, Germantown, Pa. Mar. 1, 1907

HAYNES, LOUIS HENRY Engineer, 3214 Vermon Ave., Chicago, Ill., Jan. 26, 1906

HAYS, GEORGE, 190 Belleville Ave., Bloomfield, N. J. Apr. 23, 1903

HAYS, JOHN COFFEE, President and Consulting Engineer, Mt. Whitney Power Co., Visalia, Cal. Jan. 29, 1904

HAYWARD, NATHAN, General Contract Agent, Bell Telephone Co., Philadelphia,. Pa. Aug. 25, 1905

HAZARD, ISAAC PEACE, Peacedale, R. I. Mar. 29, 1907

HAZARD, WILLIAM JONATHAN, Assistant Professor Colorado School of Mines, Golden, Colo. Mar. 27, 1903

HAZEN, WILLIAM PITT, Chief Engineer, Central Market Street Railway Co., and C. L. and S. Ry., Columbus, O. Mar. 25, 1904

HEALY, LOUIS W., Treasurer, East Liverpool Railway Co., East Liverpool, Ohio. June 26, 1891

HEANY, JOHN ALLEN, Expert, Teter-Heany Developing Co., York, Pa. Oct. 25, 1901

HEATH, WILLIS HERBERT, Engineer and Draftsman, with C. O. Mailloux; res., 9 Hanson Pl., Brooklyn, N. Y. Mar. 27, 1903

HEAVENS, FRED JOHN, Purchasing Agent, Pittsburg and Allegheny Telephone Co., Pittsburg, Pa. Mar. 29, 1907

HEDENBERG, WM. L., W. L. Hedenberg Publishing Co., 136 Liberty St., New York City. Nov. 21, 1894

HEDGER, LESLIE ARTHUR, Sec.-Treas., Metropolitan Structure Co., Inc. of S. F. Investors Building, San Francisco, Cal., Aug. 25, 1905

HEDIN, KALEB, Electrical Engineer, Fuller-Wenstrom Electrical Mfg. Co., Walthamstow, London E., Eng. Apr. 22, 1904

HEFFERNAN, JOHN T., President, Heffernan Engine Works, 108 Railroad Ave., Seattle, Wash. Nov. 24, 1905

HEFT, NATHAN HOPKINS, Chief of Electrical Dept., N. Y. & N. H. H. R. R., Bridgeport, Conn. Aug. 23, 1899

HEGEMAN, ANDREW S., Student, Polytechnic Institute; res., 7921 18th Ave., Brooklyn, N. Y. Nov. 23, 1906

HEIDENRICH, HANS EDWARD, Designing Engineer, Siemensstr. 1, Karlsruhe, Baden, Ger. Mar. 25, 1904

HEILMAN, CHARLES JONES, Electrical Engineer, 935 Monaco St., Denver, Colo. Jan. 27, 1905

HEINZE, JOHN O., Heinze Electric Co., Lowell, Mass. June 14, 1905

HEIZMANN, LEWIS JOSEPH, Assistant Treasurer and Chief Engineer, Penn. Hardware Co.; res., 318 N. 5th St., Reading, Pa. July 26, 1907

HELLEBUCK, GUSTAVE J., Electrical Engineer, Moerbeke (Waes) Belgium. Apr. 25, 1902

HELLER, HARVEY EDGAR, Superintendent, Bevney Traction Co., Salamanca, N. Y. Apr. 28, 1905

HELLICK, CHAUNCEY GRAHAM, 510 Northampton St., Easton, Pa. Jan. 26, 1898

HELLMUND, RUDOLPH E., Designing Engineer, Western Electric Co., Hawthorn; res., Hinsdale, Ill. July 28, 1905

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HELWEG-FAHNOI, HANS FREDERIK, 706 Coal St., Wilkinsburg, Pa. Mar. 29, 1907

HEMINGWAY, ALBERT FRANKLIN, Sales Dept., Wellman-Seaver-Morgan Co., First National Bank Building, Chicago, Ill. Sept. 27, 1901

HEMINWAY, CHARLES MERRITT, Treasurer and Manager, Consolidated Engine-Stop Co., 130 E. 12th St., New York City. Mar. 24, 1905

HEMPHILL, WILLIAM, Draftsman, Cataract Power & Conduit Co., 811 7th St., Buffalo, N. Y. June 15, 1904

HENDERSON, ALEX., Electrician, Sprague Electric Co.; res., 122 W. 103d St., New York City. Nov. 30, 1897

HENDERSON, CLARK TRAVIS, Salesman, Cutler Hammer Mfg. Co., Milwaukee, Wis. Mar. 25, 1904

HENDERSON, HENRY BANKS, Secretary and Treasurer Riverside Foundry & Machine Works, Riverside, Cal. May 21, 1895

HENDERSON, JOHN STEELE, JR., Salesman, W. E. & M. Co., Calvert & Baltimore Sts., Baltimore, Md. Dec. 23, 1904

HENDERSON, ROBERT H., Superintendent, Westinghouse Lamp Co., Bloomfield, N. J, Jan. 23, 1903

HENDERSON, ROY MANWARING, Engineer, Stone & Webster, Engineering Corporation, 84 State St., Boston, Mass. June 21, 1907

HENDREY, W. R., Salesman, Stanley G. I. Electric Mfg. Co., 410 Coleman Building, Seattle, Wash. May 15, 1905

HENDRICKSON, EVERETT HOUSE, Mare Island Navy Yard; res., 538 Georgia St., Vallejo, Cal. Nov. 24, 1905

HENDRY, WILLIAM FERRIS, Factory Engineer, Western Electric Co., 463 West St., New York City. Apr. 23, 1903

HENNINGER, PHILIP EDGAR, Westinghouse Electric and Mfg. Co., 2072 Military St., Port Huron, Mich. Apr. 28, 1905

HENRY, ARTHUR ROBERT, Ross & Holgate, 80 Francois Xavier St., Montreal, Que. July 28, 1903

HENRY, ARTHUR SEYMOUR, Construction Department, Western Electric Co.; res., 634 E. 139th St., New York City. Jan. 25, 1907

HENRY, GEORGE CLINTON, District Manager, Bullock Electric Mfg. Co., Atlanta, Ga. Jan. 3, 1902

HENRY, GEORGE J., JR., Engineer, The Pelton Water Wheel Co., 19th and Harrison Sts., San Francisco, Cal. Apr. 27, 1898

HENRY, IRA WALTON, Electrical Engineer, 149 Broadway, New York City. May 21, 1901

HENRY, SIDNEY MORGAN, Assistant Naval Constructor U. S. Navy, Mare Island, Cal. May 14, 1906

HENSHAW, ARTHUR WILLISTON, 750 Nott St., Schenectady, N. Y. Dec. 28, 1906

HERBERT, EDWARD, Western Electric Co., 259 South Clinton St.; res., 111 Loomis St., Chicago, Ill. Oct. 24, 1902

HERMAN, JOSEPH W., Inspector, Switchboard Drafting Department, General Electric Co., Schenectady, N. Y. Mar. 29, 1907

HERON, CHARLES ALEXANDER, Draftsman, Indianapolis Traction & Terminal Co., Indianapolis, Ind. Sept. 28, 1906

HERR, EDWIN M., First Vice-president, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Jan. 25, 1907

HERZOG, JOSEF, Chief of Installations Department, Ganz & Co., V. Elisabetplatz, 1 Budapest, Austria-Hungary. Jan. 3, 1902

HESKETH, JOHN, Chief Electrical Engineer, Postmaster General's Department, Melbourne, Victoria. May 21, 1901

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HESS, ADOLFO G. B., via Principe Amedeo 22, Torino, Italy. Nov. 20, 1903

HESS, HERBERT H., Assistant in Transformer Eng'g Department, General Electric Co., Schenectady, N. Y. Apr. 23, 1903

HESS, WILHELM, Compagnie d'Electricite Alirth, Basel-Murchenstein, Switzerland. June 21, 1907

HESTON, CHARLES ELISHA, District Engineer, U. S. Signal Corps, Port Townsend, Wash. May 15, 1905

HEWETT, JOHN RIDGE, Engineer, Railway Engineering Department, General Electric Co., Schenectady, N. Y. Mar. 1, 1907

HEWITT, CHARLES E., President, C. E. Hewitt & Co., Park Row Building, New York City. Sept. 25, 1895

HEWITT, JOHN MARSHALL, Student, Cornell University, Ithaca, N. Y. May 14, 1906

HEWITT, WILLIAM R., Chief, Department of Electricity, City Hall Court, San Francisco, Cal. May 15, 1894

HEWITT, HOWARD BEARLEY, 249 E. Logan Sq., Philadelphia, Pa. Apr. 26, 1907

HEWLETT, EDWARD M., Engineer, General Electric Co.; res., 27 University Pl., Schenectady, N. Y. May 19, 1891

HEYWOOD, JAMES, Assistant Superintendent, Philadelphia Rapid Transit Co., 820 Dauphin St., Philadelphia, Pa. Dec. 23, 1904

HIBBARD, TRUMAN, Secretary and Treasurer, Electrical Machinery Co.; res., 4816 Penn. Ave. S., Minneapolis, Minn. June 15, 1904

HICKOK, FREDERICK S., Electrical Engineer, Case Manufacturing Co., 824 Marquette Building, Chicago, Ill. Apr. 23, 1903

HICKS, THOMAS NORMAN, Assistant Electrical Engineer, Brooklyn Edison Co.; res., 67 Gates Ave., Brooklyn, N. Y. Mar. 23, 1906

HIGGINS, WARREN SNEDEN, Western Electric Co., New York City; res., 12 Seventh Ave., Brooklyn, N. Y. June 14, 1905

HILBERT, ALFRED, Draftsman, 218 E. 11th St., New York City. Apr. 22, 1904

HILBORN, DAVID SIDNEY, Cable Tester, Bell Telephone Co.; res., 2146 N. 12th St., Philadelphia, Pa. May 14, 1906

HILD, FREDERICK WALDORF, Consulting Engineer, Dubuque, Iowa. Oct. 28, 1904

HILDBURGH, WALTER L., St. Ermin's Hotel, Westminster, London, Eng. Dec. 28, 1898

HILDEBRANDT, HENRY A., St. Peter, Minn. Apr. 28, 1905

HILL, ARTHUR ST. JOHN, Student, Polytechnic Institute of Brooklyn, N. Y.; res., Norwalk, Conn. June 21, 1907

HILL, CHARLES B., Vice-president and Manager, Cooper-Hewitt Electric Co., 111 Broadway, New York City. May 15, 1905

HILL, FREDERICK WARREN, Chief Engineer, Phoenix Electric Mfg. Co., Mansfield, Ohio. June 14, 1905

HILL, G. HENRY, 1540 Union St., Schenectady, N. Y. Jan. 25, 1899

HILL, GEORGE WILLIAM, Engineer, Electric Storage Battery Co., 60 State St., Boston, Mass. Jan. 29, 1904

HILL, HALBERT PAUL, 609 W. 137th St., New York City. Aug. 17, 1904

HILL, MALCOLM WESCOTT, Electrical Engineer and Contractor, 405 Courtland St., Baltimore, Md. Feb. 24, 1905

HILL, NICHOLAS S., JR., Consulting Engineer, 100 William St., New York City. Aug. 5, 1896

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HILL, ROY W., Patent Attorney, 1463 Monadnock Block, Chicago, Ill. Oct. 27, 1905

HILL, W. H., Assistant Superintendent, Con. Dept., New York Edison Co., New York City. Aug. 17, 1904

HILL, JOSEPH S., Chief Engineer Department of Interior, 8th and E Sts., N. W., Washington, D. C. Apr. 26, 1907

HILL, THOMAS A., Consulting Engineer, and Attorney 170 Broadway, New York City. June 21, 1907

HILL, WILLIAM AMEAL, Electrician, Pope Motor Car Co., 1544 Macomber St., Toledo, O. June 21, 1907

HILLIARD, FRANK WYMAN, General Electric Co., Chicago, Ill. Dec. 15, 1905

HILLIARD, JOHN D., JR., Electrical Engineer, Hudson River Water Power Co., Glens Falls, N. Y. June 19, 1903

HILLIARD, THOMAS WILLIAM NICHOLLS, Engineer, Canadian General Electric Co., 178 Hollis St., Halifax, N. S. Mar. 27, 1903

HILLMAN, H. W., Morton House, Detroit, Mich. Jan. 3, 1902

HILLMAN, WILLIAM BENNETT, Superintendent of Construction, U. S. Reclamation Service, Natchez City, Wash. Mar. 1, 1907

HINDERT, EDWIN GEORGE, Chief Mechanical and Electrical Engineer, C. & S. W. Traction Co., Elyria, Ohio. Nov. 20, 1903

HINRICHSEN, EDWARD E., Telephone Engineer, Western Electric Co., Chicago, Ill. June 21, 1907

HIROKAWA, TOMOKICHI, Chief Engineer, Kyoto Electric Light Co., Kyoto, Japan. Dec. 18, 1903

HIRSHFELD, CLARENCE FLOYD, Assistant Professor of Power Engineering, Cornell University, Ithaca, N. Y. Feb. 24, 1905

HISS, WILLIAM JACOB, JR., New York Telephone Co., 15 Dey St.; res., 357 W. 115th St., New York City. Apr. 26, 1907

HITZEROTH, L. D., Engineer, Century Electric Co., 18 Fell St., San Francisco, Cal. July 26, 1900

HIXON, ALFRED, J., with E. C. Lewis, 121 Federal St., Boston, res., Braintree, Mass. June 21, 1907

HIXSON, CLINTON JEROME, Railway Engineering Equipment Dept., General Electric Co., Schenectady, N. Y. Nov. 21, 1902

HOADLEY, GEORGE A., Professor of Physics, Swarthmore College, Swarthmore, Pa. May 19, 1903

HOAG, GEO. M., Cherryvale Electric Light & Power Co., Cherryvale, Kan. Apr. 28, 1897

HOAG, STEPHEN ASA, Electric and Hydraulic Engineer, Oregon Short Line Railway Co., Salt Lake City, Utah. Dec. 15, 1905

HOAR, WILLIAM JOHN, Manager, American Telephone and Telegraph Co., Troy; res., 925 3d Ave., Upper Troy, N. Y. Oct. 28, 1904

HOBBLE, ARTHUR CASSON, Cauvery Falls Power, Scheme Livasamudram Mysore Prov., India. Mar. 27, 1903

HOBBS, HENRY WEBSTER, Electrical Engineer, U. S. Engineers' Office, Portland, Me. Mar. 24, 1905

HOBEIN, CHARLES AUGUSTUS, JR., Electrical Department, United Railways Co., St. Louis, Mo. June 19, 1903

HODGE, CHARLES, Salesman, Westinghouse E. & M. Co., National Bank of Commerce Building, St. Louis, Mo. Mar. 28, 1902

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HODGE, ROBERT WALTER, President Hodge-Walsh Elec. Eng'g Co.; res., 3528 Central St., Kansas City, Mo. Jan. 23, 1903

HODGES, GEORGE HANWOOD, Electrical Engineer, The New York Telephone Co., 15 Dey St., New York City. Apr. 23, 1903

HODGES, WILLIAM LEMMON, Engineering Department, Southern Bell Tel. & Tel. Co., Atlanta, Ga. Apr. 26, 1901

HODGKINSON, FRANCIS, Mechanical Engineer, The Westinghouse Machine Co., East Pittsburg, Pa. May 20, 1902

HODGSON, CECIL, Electrical Engineer, 106 75th St., Chicago, Ill. Sept. 26, 1902

HODGSON, JOSEPH ERNEST, Engineer, United Gas Improvement Co., Philadelphia, Pa. Apr. 23, 1903

HOEFTMANN, ALEXANDER O., Superintendent of Electric Cable Works, American Steel and Wire Co., Worcester, Mass. May 19, 1903

HOEN, WILL MARK, Comania Minera Las Das Estrellas, Tlalpujahua, El Oro, Mexico. Jan. 26, 1906

HOFF, CHRISTOPHER, JR., Electrical Engineer, Lee and Hoff Manufacturing Co.; res., 213 Aurora Ave., St. Paul, Minn. June 21, 1907

HOFF, EARL BOURIE, Electrician, Ft. Wayne Electric Co., Ft. Wayne, Ind. June 21, 1907

HOFFMAN, ARTHUR HENRY, Instructor in Physics and Electrical Engineering, Iowa State College, Ames, Iowa. Apr. 27, 1906

HOFFMAN, FRANK, Electrical Engineer, Owl Creek, Mo. Sept. 25, 1903

HOFFMAN, WILLIAM LEVI, Electrical Engineer, Columbia Improvement Co.; res., 404 No. G St., Tacoma, Wash. Oct. 23, 1903

HOFFMANN, BERNHARD, New York Telephone Co., 15 Dey St., New York City. Nov. 23, 1898

HOFFMEISTER, FREDERICK, Erecting Engineer, Canadian General Electric Co., 14 East King St., Toronto, Ont. July 28, 1905

HOGAN, CHARLES WILLIAM, Holscher Electric Mfg. Co., Warren, Ohio. Mar. 28, 1902

HOGAN, THOMAS JEFFERSON, N.Y. Electric Installation Co.; res., 130 W. 25th St., New York City. Sept. 25, 1903

HOGLE, CHARLES EDWARD, U. S. Reclamation Service, Deerfield, Kansas. Sept. 25, 1903

HOLBERTON, GEORGE C., General Supt., Electric Dept., Oakland Gas, Light and Heat Co., 13th & Clay Sts., Oakland, Cal. May 15, 1894

HOLBROOK, FREDERICK MONTGOMERY, Electrical Engineer, Crocker-Wheeler Co., Old Colony Building, Chicago, Ill. Sept. 27, 1901

HOLCOMB, EUGENE, Manager Foreign Department, Allis-Chalmers Co., Milwaukee, Wis. July 28, 1903

HOLDEN, CHRISTOPHER, Assistant Electrical Enginere, Carnegie Library, Power Construction Dept., Winnipeg, Man. Apr. 26, 1907

HOLDEN, EDGAR B., JR., Electrical Engineer, with Viele, Cooper & Blackwell, 49 Wall St., New York City. Sept. 25, 1903

HOLDEN, SAMUEL SPRAGUE, Student, Brooklyn Polytechnic Institute; res., 237 Quincy St., Brooklyn, N. Y. Jan. 25, 1907

HOLDREGE, HENRY ATKINSON, General Manager, Omaha Electric Light & Power Co., N. Y. Life Building, Omaha, Neb. Sept. 25, 1903

HOLLADAY, LEWIS LITTLEPAGE, Adj. Professor Appl. Math., University of Va., University Sta., Charlottesville, Va. May 15, 1905

HOLLAND, NEWMAN HENRY, Telephone Engineer, Western Electric Co., 259 So. Clinton St., Chicago, Ill. Apr. 22, 1904

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HOLLAND, WALTER E., Experimenter at Edison Laboratory, Orange, N. J. Aug. 17, 1904

HOLLAND, WAYMAN A., JR., Electrical Switchboard Engineer, General Electric Co.; res., 637 Terrace Pl., Schenectady, N. Y. Apr. 26, 1907

HOLLEY, CARL HIRAM, Chief Engineer, The Mt. Whitney Power Co., Brown Building, Visalia, Cal. Sept. 26, 1902

HOLLINS, GEORGE GRUNDY, J. G. White & Co., 43 Exchange Pl., New York City. Mar. 27, 1903

HOLLIS, VENNING PALMER, Secretary, Hollis Electric Co., 311 2d Ave., So. Minneapolis, Minn. Sept. 28, 1906

HOLLOS, JOSEPH, Technical Counselor, Ministry of Commerce, Budapest, Austria-Hungary. May 19, 1903

HOLMAN, ARTHUR ELIOTT, Draughtsman, Pressed Steel Car Co., Pittsburg; res., 203 Trenton Ave., Wilkinsburg, Pa. Sept. 28, 1906

HOLMAN, GEORGE ULYSSES GRANT, Engineer, H. W. Johns Manville Co., 55 High St., Boston, Mass. Apr. 25, 1902

HOLMGREN, GUSTAF, Electrical Designer, Allmanna Syenska Elektriska Akticbolaget, Elektriska, Westeras, Sweden. Mar. 24, 1905

HOLMGREN, TORSTEN, Kungl. Trollhatte Kanal & Vattenoerk, Trollhattan, Sweden. Aug. 17, 1904

HOLST, ENGELHARDT WILBOREN, Superintendent, Old Colony Street Railway Co., Brockton, Mass. June 14, 1905

HOLSTEIN, OTTO, Atlantic De Forest Wireless Co., 42 Broadway, New York City. Apr. 26, 1907

HOLT, MARMADUKE BURRELL, Mining and Electrical Engineer, Silverton, Colo. Apr. 15, 1890

HOLTBY, ALFRED CHARLES, Consulting Electrical Engineer, S. Newman & Co., Johannesburg, S. A. Aug. 17, 1904

HOLTZER, CHAS. WM., President, Holtzer-Cabot Electric Co., Brookline, [Life Member.] Mass. May 21, 1901

HOLZ, OTTO, Engineer, General Electric Co.; res., 417 Rugby Road, Schenectady, N. Y. Nov. 24, 1905

HOMMEL, LUDWIG, 9th & Liberty Sts., Pittsburg, Pa. Jan. 20, 1897

HONNOLD, ORVILLE A., Electrical Engineer, Utah Light and Power Co., Salt Lake City, Utah. Feb. 27, 1903

HONEY, WILLIAM, Electrical Engineer, Cia Hidro-Electric Queretara, Querataro, Mex. Feb. 27, 1903

HONEYMAN, PAUL DEPUE, Division Construction Superintendent, New York Telephone Co., 15 Dey St., New York City. Apr. 26, 1907

HOOKER, HENRY KEENE, Clerk, N. W. Harris & Co., Boston; res., Wellesley Hills, Mass. Apr. 26, 1907

HOOPER, GEORGE HEBERTON, JR., Edison Laboratory, Orange; res., 44 William St., West Orange, N. J. Aug. 25, 1905

HOOPER, JAMES KIMBALL, Economical Electric Lamp Co., 96 Warren St.; res., 80 Manhattan Ave., New York City. July 19, 1904

HOOPES, WILLIAM, Electrical Engineer, Aluminum Co. of America, Pittsburg, Pa. Aug. 17, 1904

HOPE, HARRY MILFORD, Electrical Engineer, Stone & Webster Corporation, 84 State St., Boston, Mass. Apr. 23, 1903

HOPE, HARRY LEROY, Telephone Salesman, Western Electric Co., 259 South Clinton St., Chicago, Ill. June 21, 1907

HOPE, ROBERT DEVERE, JR., Student, Brooklyn Polytechnic Institute; res., 147 State St., Brooklyn, N. Y. Nov. 23, 1906

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HOPPENSTEDT, EDWARD HENRY, Clerk, B. H. Howell Son and Co., 109 Wall St., New York City. June 21, 1907

HOPEWELL, CHAS. F., Fire Alarm and Police Telegraph, City of Cambridge, City Hall; res., Cambridgeport, Mass. Aug. 13, 1897

HOPKINS, NEVIL MONROE, *M.S.*, Professor of Electrochemistry, George Washington University, Washington, D. C. Nov. 20, 1895

HOPKINS, N. S., Consulting Engineer, Williamsville, N. Y. Apr. 27, 1898

HOPKINS, RICHARD M., Nat. Dist. Tel. Co., 44 E. 23d St., New York City. Apr. 27, 1906

HOPKINS, ROBERT MILNE, Alburger Condenser Co., 95 Liberty St., New York City. Nov. 20, 1903

HOPKINS, ROBERT S., Standard Underground Cable Co., 56 Liberty St., New York City. July 28, 1903

HORN, HAROLD J., *E.E.*, Assistant Superintendent, Bare Wire Department, John A. Roebling's Sons' Co., Trenton, N. J. Mar. 22, 1899

HORNE, SANDFORD HENRY, Manager and Engineer, Independent Electric Construction Co., 381 Fulton St., San Francisco, Cal. Mar. 25, 1904

HORNER, LEONARD SHERMAN, Representative, Crocker-Wheeler Co., 42 Church St., New Haven, Conn. June 15, 1904

HORNING, WALTER R., Manager, Robbins & Myers, 337 Frankfort Ave., N. W., Cleveland, O. July 28, 1905

HORRY, WILLIAM SMITH, Electrician, Union Carbide Co., Niagara Falls, N. Y. Dec. 19, 1902

HORTING, LEVI W., Electrical Engineer, Fidelity Electric Co.; res., 316 Pine St., Lancaster, Pa. Dec. 15, 1905

HORTON, HARRY MAC, Chief Assistant, American de Forest Wireless Telegraph Co., 42 Broadway, New York City. Jan. 27, 1905

HORTON, LOUIS S., Student, Clemson College; res., 639 W. Market St., Anderson, S. C. Nov. 23, 1906

HORTON, WALTER H., Superintendent and Engineer, Rutland Railway Light and Power Co., Rutland, Vt. Apr. 26, 1907

HOSFORD, DANIEL MASON, 2202 E. 93d St., Cleveland, O. Mar. 1, 1907

HOSKINS, WALTER S., Salesman, Kilbourne & Clark Co.; res., 1428 21st Ave., Seattle, Wash. Aug. 25, 1905

HOTSON, ALEXANDER DENIS, Electrician, British Columbia Electric Railway Co.; res., 976 Burrard St., Vancouver, B. C. May 15, 1905

HOUGH, BENJAMIN KENT, Electrical Engineer, Edison Electric Illuminating Co., 3 Head Pl., Boston, Mass. Apr. 25, 1902

HOUGH, ROBERT HARBISON, Instructor in Physics, University of Pennsylvania, Philadelphia, Pa. Jan. 25, 1907

HOUK, RUDOLPH J., 2d Assistant Elec. Operator, Interborough Rapid Transit Co., 59th St. and 11th Ave., New York City. Mar. 27, 1903

HOUCK, HENRY CRAFT, Manager Supply Department, General Electric Co., Cincinnati, Ohio. June 21, 1907

HOUSE, ROBERT CLEMENTS, Inspector on Electrical Subways, L. B. Stillwell, 100 Broadway, New York City. Apr. 26, 1907

HOUSE, R. MORTON, Construction Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. June 14, 1905

HOUSKEEPER, WILLIAM GIBBONS, Westinghouse Electric & Mfg. Co., Land Title Building, Philadelphia, Pa. Nov. 24, 1905

HOUSTON, SAMUEL, Construction Department, General Electric Co., Schenecady, N. Y. Oct. 23, 1903

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HOVEY, ALBERT FREDERICK, Cable Engineer, Interborough Rapid Transit Co.; res., 210 W. 107th St., New York City. Apr. 26, 1907

HOVLAND OLE C., Automatic Telephore Switchboard Inspector, The Automatic Electric Co., Chicago Ill. May 19 1903

HOWARD, BENJAMIN C., Assistart to Secretary, Consolidated Gas, Electric Light and Power Co., Baltimore; res. Rider, Md. Mar. 24 1905

HOWARD, ERNEST GRANT, Electrical Engineer, Coffin Valve Mfg. Co., Neponset, Mass. Apr. 23 1903

HOWARD, LEMUEL FREDERIC, Assistant Electrical Engineer, Union Switch and Signal Co., Pittsburg, Pa. Mar. 23 1906

HOWE, JAMES CARLETON, Manager, Missouri & Kansas Telephone Co., St. Joseph, Mo. Dec. 19 1902

HOWE, WINTHROP KEITH, Chief Engineer, General Railway Signal Co., 1738 Elmwood Ave., Buffalo N. Y. Mar. 22 1901

HOWELL, CECIL ASHBROOKE, 2507 Juliet St., Los Angeles, Cal. May 17 1904

HOWELL, DAVID JANNEY, Secretary-Treasurer and Manager, Welch Water, Light and Power Co., Washington, D. C. Sept. 25 1903

HOWES, ROBERT, Construction Superintendent, Loring N. Farnum Co., 53 State St., Boston, Mass. Jan. 25 1901

HOWK, CLARENCE LEROY, Telephone Engineer, Western Electric Co.; res., 1143 W. Fullerton Ave., Chicago, Ill. June 21, 1907

HOWSON, HUBERT, Patent Lawyer, 38 Park Row. New York City. June 8 1887

HOXIE, GEORGE L., 45 Broadway, New York City. Feb. 28 1901

HOXIE. HALL FARRINGTON, Electrical Engineer, 120 Broadway, New York City. Oct. 24 1902

HOXIE, FREDERICK JEROME, Inspector, Associated Factory, Mutual Fire Insurance Co., Phenix, R. I. July 26, 1907

HOY, HOWARD HARTMAN. Instructor in Electrical Engineering, So. Dakota State College of A. and M. A, Brookings, S. D. June 21, 1907

HOYT, PETER V., Sales Engineer, National Battery Co., 1765 Broadway; res., 509 W. 170th St., New York City. Apr. 27 1906

HUBBARD, ALBERT S., Chief Engineer, Gould Storage Battery Co., 347 Fifth Ave., New York City. Nov. 20 1895

HUBBARD, CHESTER DIMOCK, Electrical Engineer, Electric Storage Battery Co., Philadelphia, Pa. Apr. 28 1905

HUBBS, JOHN H., United Gas Improvement Co., Broad and Arch Sts., Philadelphia. Pa. Jan. 27 1905

HUBRECHT, DR. H. F. R., Director, Nederlandsche Bell Telephone Co., Amsterdam, Holland. Oct. 4 1887

HUDDLE, DAVID FRANKLIN, JR., Switchboard Department, General Electric Co.; res., 25 N. Ferry St., Schenectady, N. Y, Sept. 28 1906

HUDGSON, JOHN HOWARD, Draftsman, 2123 4th Ave., Seattle, Wash. Dec. 18 1903

HUDSON, HARRY PRATT, Power and Mining Department, General Electric Co.; res., 226 McClellan St., Schenectady, N. Y. Sept. 26 1902

HUELS, FREDERICK WILLIAM, Instructor in Experimental Engineering, University of Wisconsin, Madison, Wis. Dec. 18, 1903

HUFFMAN, JOHN C., Sales Engineer, Canadian Westinghouse Co., Calgary, Alberta Provence, Can. Feb. 24, 1905

HULBERT, JOHN W., JR., Chief Electrician, Auburn State Prison; res., 42 Seminary St., Auburn, N. Y. June 21, 1907

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HULME, FREDERICK WENDELL, Electrical Engineer, Gould Storage Battery Co., 347 Fifth Ave., New York City. Apr. 22, 1904

HULL, HERBERT LADSON, JR., Traveling Electrical Salesman, Ewirg Merkle Electiic Co., Fort Worth, Tex. Apr. 26, 1907

HUMISTON, JOHN MEANS, The Chicago Telephone Co., 230 Washington St.; res., Berwyn, Ill. May 19, 1903

HUMPHREY, CALVIN B.,Office Manager, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Apr. 25, 1902

HUMPHREY, CLIFFORD WANE, Consulting Engineer, The Rookery, Chicago., Ill. Mar. 27, 1903

HUMPHREY, ORMAN BROWN, Consulting Engineer, 202 Exchange St.; Bangor, Me. Sept. 28, 1906

HUMPHREYS, C. J. R., Humphreys and Glasgow, 31 Nassau St., New York City. Sept. 6, 1887

HUNSICKER, HARRY JOSEPH, Assistant Electrical Engineer, Hudson River Electric Power Co., 82 State St., Albany, N. Y. Mar. 1, 1907

HUNT, ARTHUR L., Harrisburg Foundry and Machine Works, 114 Liberty St., New York City. Sept. 19, 1894

HUNT, CHARLES WALLACE, President, C. W. Hunt Co., 45 Broadway, New York City. Apr. 25, 1902

HUNT, FRED L., Construction Department, General Electric Co., 84 State St., Boston, Mass. Apr. 28, 1905

HUNT, H. H., District Manager, Stone and Webster, 113 31st St. E., Savannah, Ga. June 21, 1907

HUNT, JOHN HERMAN, Department of Electrical Engineering, Ohio State, University, Columbus, Ohio. June 21, 1907

HUNT, ROBERT G., H. M. Byllesby & Co., American Trust Building, Chicago, Ill. Sept. 22, 1905

HUNT, SAMUEL PARKER, Electrical Engineer, 747 Union St., Manchester,
[Life Member.] N. H. Apr. 23, 1903

HUNT, WALTER SIMEON, 21 Upper Hamilton Terrace, London S. W., Eng. Apr. 23, 1903

HUNTER, CHARLES FREDERICK, Assistant Electrical Inspector, State Commission Gas and Electricity, Albany, N. Y. May 15, 1905

HUNTER, MADONE C., Electrical Engineer, St. Joseph R. R. Light, Heat & Power Co., St. Joseph, Mo. Sept. 26, 1902

HUNTLEY, CHAS. R., General Manager, Buffalo General Electric Co., 40 Court St., Buffalo, N. Y. Sept. 25, 1895

HUPER, CARL, Electrical Draftsman, with W. J. Gray; res., 3706 Thomas Ave., S., Minneapolis, Minn. Mar. 29, 1907

HURD, BENJAMIN, President, Hurd and Haggin, 316 Hudson St., New York City; res., Nutley, N. J. Apr. 26, 1907

HURDELL, VICTOR HOLLISTER, Salesman, Westinghouse Electric and Mfg. Co., 716 Board of Trade Building, Boston, Mass. Mar. 29, 1907

HURLBATT, DOUGLASS GRAY, Assistant Engineer, Siemens Bros., York Mansion, Westminister, London. Mar. 29, 1097

HURLBERT, FRANCIS WYMOND, Foreign Dept., General Electric Co., 44 Broad St., New York City. July 19, 1904

HURLBUT, HENRY S. G., Assistant Electrical Engineer, Toropah Mining Co., Tonopah, Nev. Dec. 28, 1906

HURTZ, LEONARD EUGENE, General Manager, Lincoln Telephone Co., Lincoln, Neb. Mar. 23, 1906

HUSBERG, TAGE WILLIAM, Draughtsman, N. Y. Edison Co., New York City. Nov. 23, 1906

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HUSSEY, ABE, Superintendent of Cables, N. Y. C. & H. R. R.R. Co., Highbridge, New York City. Oct. 26, 1906

HUSSEY, HARRY BRIGHAM, Manager, Crocker-Wheeler Co., 817 O. C. S. Bank Building, Syracuse, N. Y. Nov. 23, 1906

HUSSEY, RICHARD BYRON, Assistant Engineer, General Electric Co., West Lynn, Mass. Mar. 24, 1905

HUTCHINGS, JAMES TYLER, Electrical Engineer Assistant, Rochester Railway and Light Co., Rochester, N. Y. Apr. 23, 1903

HUTCHINSON, FREDERICK L., American Institute Electrical Engineers, 33 W. 39th St., New York City. June 20, 1894

HUTCHINSON, ROLIN WILLIAM, JR., Publicity Dept., Westinghouse Electric & Mfg Co., Pittsburg, Pa. Jan. 3, 1902

HUTCHISON, HARRISON D., 1A Primavera No. 4, Tacubaya, Mexico. Feb. 24, 1905

HUTHSTEINER, ROBERT EDWARD, Assistant Engineer, Switchboard Department, General Electric Co., Schenectady, N. Y. Sept. 28, 1906

HUTTON, ROBERT ERNEST, Secretary, Treasurer and Manager, Lexington Light and Power Co., Lexington, Va. Sept. 28, 1906

HUTTON, SOL E., Assistant Professor of Mechanical Engineering, University of Kansas, Lawrence, Kan. Mar. 23, 1906

HYDE, ERNEST NOYES, Salesman, F. H. Stewart Electric Co., 35 N. 7th St., Philadelphia, Pa. Aug. 25, 1905

HYDE, JAMES CLARK, Chartered Acct. Trustee and Commissioner, 306 Merchants' Bank Chambers, Montreal, Que. Apr. 23, 1903

HYDE, WILLIAM ALBERT, Electrical Expert and Draftsman, Bureau of Ordnance, Navy Department, Washington, D. C. July 26, 1907

HYNES, WILDRIE FREEMAN, Construction Engineer, Allis-Chalmers Co., 71 Broadway, New York City. Apr. 26, 1907

HYLAND, JOHN FRANCIS, Foreman of Maintenance, New England Telephone and Telegraph Co., Boston, Mass. Mar. 29 1907

HYMAN, WALLACE MUNROE, Assistant P. R. Moses; res., 11 E. 80th St., New York City. May 17, 1904

IDELL, FRANK E, Havemeyer Building, 26 Cortlandt St., New York City. July 12, 1887

IIJIMA, ZENTARO, Electrical Engineer, Iijima Transformer Co., Minami Shinagawa, Tokyo, Japan. Jan. 22, 1896

INCH, SYDNEY RICHARD, [*Local Secretary*] Superintendent and Manager, Missoula Light and Water Co., Missoula, Mont. Aug. 17, 1904

INGERSOLL, JOHN BORLAND, Chief Electrical Engineer, Spokane Inland Ry. Co., Terminal Bldg., Spokane, Wash. Dec. 18, 1903

INSULL, JOSEPH, Assistant, C. C. Chesney, Stanley G. I. Electrical Mfg. Co.; res., 46 Bartlett Ave., Pittsfield, Mass. July 28, 1903

INSULL, MARTIN, J., United Gas & Electric Co., New Albany Ind. Ill. Nov. 22, 1899

INSULL, SAMUEL, President, Chicago Edison Co. 139 Adams St. Chicago, Ill. Dec. 7, 1886

IREMONGER, ROBERT S., Engineer, N. Y. and N. J. Telephone Co., 547 Clinton Ave.; res, 319 Quincy St., Brooklyn, N. Y. Apr. 26, 1907

ISHLER, WILLIS ALDEN, Assistant Engineer, General Electric Co., Pittsfield, Mass. Sept. 28, 1906

IWADARE, KUNIHIKO, Electrician, Nippon Electric Company, 2 Mita Shikokumachi Shibaku, Tokyo, Japan. Sept. 20, 1893

IYAR, T. S. Swaminatha, Line Inspector, Cauvery Power Scheme, Basavangudi Bangalore India. Mar. 23, 1906

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JACKSON, AUGUSTUS W., Pacific Light and Power Co., 254 South Los Angeles St., Los Angeles, Cal. Sept. 28, 1906

JACKSON, CHARLES, Electrician, La Compaña Industrial de Guadalajara, Guadalajara, Mexico. Jan. 29, 1904

JACKSON, CLARENCE CHARLES, Designing Engineer, American Transformer Co.; res., 59 Burnet St., Newark, N. J. Jan. 25, 1907

JACKSON, HENRY DOCKER Consulting Electrical Engineer, 88 Broad St., Boston, Mass. Apr. 23, 1903

JACKSON, HENRY WHITING, Chief Engineer, Westinghouse Lamp Co., 510 W. 23d St., New York City. Jan. 25, 1907

JACKSON, PHILIP T., Construction Department, New York & New Jersey Tel. Co., Newark, N. J. Mar. 25, 1904

JACKSON, RAY PHILIP, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Sept. 28, 1906

JACKSON, WILLIAM S., Foreman Electrical Department Long Island R.R. Co., Wood Haven Junction, L. I., N. Y. Mar. 24, 1905

JACKSON, WILLIAM THOMAS, Electrical Inspector, Board of Fire Underwriters of the Pacific, Butte, Mont. Oct. 27, 1905

JACOBI, WILLIAM HENRY, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. June 14, 1905

JACOBSON, JULIUS R., Special Employee, General Electric Co., Schenectady; res., 310 Almond St., Syracuse, N. Y. Oct. 24, 1902

JACOBUS, DAVID SCHENCK, Advisory Engineer, Babcock & Wilcox Co., 85 Liberty St., N. Y. City. Sept. 25, 1903

JAEGER, CHARLES L., Inventor, Electric Recording Ship Apparatus, Laboratory, 132 Mulberry St., New York, N. Y. Dec. 20, 1893

JALONICK, HARTWELL, Commercial Department, General Electric Co., Schenectady, N. Y. Oct. 26, 1906

JAMES, HENRY DUVALL, *B. S., M.E.*, [*Local Secretary*] Engineer, Westinghouse E. & Mfg. Co., Pittsburg, Pa. Nov. 23, 1898

JAMES, HENRY PHILIP, Electrical Engineer, Bryant Electric Co., 905 Howard Ave., Bridgeport, Conn. June 21, 1907

JAMES, TUDOR CONWAY, Allis-Chalmers-Bullock Co., Montreal Que. Feb. 27, 1903

JAMESON, CHARLES SMITH, Assistant Foreman Installation and Meter Department, General Electric Co., Lynn, Mass. May 19, 1903

JANES, CLAUDE MINNIS, Superintendent of Electrical Construction, Juniata Hydro Electric Co., Huntingdon, P. Q. Apr. 23, 1903

JANNEY, WILLIAM CANBY, Electrical Engineer, United Gas & Improvement Co., Broad & Arch Sts., Philadelphia, Pa. June 19, 1903

JANSKY, CYRIL M., Professor of Physics and E. Engineering, University of Oklahoma, Norman, Okla. Jan. 26, 1906

JAQUAYS, HOMER M., 11 Lorne St., Montreal, P. Q. Dec. 27, 1899

JARCHO, ISAIAH, Electrical Engineer, Research Corporation, N. Y. C. & H. R. R.R. Co., New York City. Dec. 18, 1903

JEFFREY, JOHN RUSSELL, Assistant General Manager Sales, Bullock Electric Mfg. Co., Cincinnati, Ohio. Dec. 19, 1902

JENKINS, ALEXANDER THOMAS, Field Engineer, Central District and Printing Telegraph Co., 416 7th Ave., Pittsburg, Pa. Jan. 29, 1904

JENKINS, JOHN EVAN, General Inspector 7th Dist., Western Union Telegraph Co., 708 Orange St., New Haven, Conn. Mar. 27, 1903

JENNENS, WALTER S., 431 Thompson St., Ann Arbor, Mich. June 15, 1904

JENNISON, ERNEST NEWTON, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 1, 1907

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JENNISON, HERBBRT CHARNOCK, Assistant in Laboratory, Coe Brass Mfg. Co.; res., Ansonia, Conn. Apr. 28, 1905

JENNINGS, JAMES T., Electrical Engineer, Philadelphia and Reading Coal and Iron Co., Pottsville, Pa. July 26, 1907

JESSOP, FRANCIS WOODWARD, Superintendent. Electric Controller and Supply Co.; res., 261 Genessee Ave., Cleveland, O. Sept. 22, 1905

JESSUP, WARREN CANFIELD, Sales Engineer, Cutter Co., 120 Liberty St., New York City. Sept. 25, 1903

JEWETT, EDWIN, HALE, Master Mechanic, Libbey Glass Co.; res., 326 Stickney Ave., Toledo, O. July 26, 1907

JEWETT, FRANK BALDWIN, Engineering Dept., A. T. & T. Co., 125 Milk St., Boston; res., 36 Wren St., W. Roxbury Mass. Jan. 23, 1903

JEWSON, FRANK KNIGHT, Telephone Engineer, The Western Electric Co., North Woolwich, England. May 19, 1903

JIMINEZ, REMIGIO, Engineer, Havana Gas and Electric Co., 1 Monte Havana, Cuba. Mar. 23, 1906

JODREY, ELBERT WEED, Assistant Foreman, General Electric Co., Lynn; res., 104 Federal St., Salem, Mass. July 28, 1905

JOHANN, CHARLES SHEPPARD, District Representative, Westinghouse Machine Co., Continental Trust Bldg., Baltimore, Md. Dec. 19, 1902

JOHNSON, ARTHUR EDWARD, Designer, Ordnance Office, War Department, 1514 Q St. N. W., Washington, D. C. Apr. 27, 1906

JOHNSON, CHARLES WOOD, Works Staff, Westinghouse Elec. & Mfg. Co., Pittsburg, Pa. Feb. 27, 1903

JOHNSON, FRANCIS PORTER, Manager, Electrical Dept., Fairbanks Morse & Co., Detroit, Mich. Mar. 27, 1903

JOHNSON, GEORGE FRIEDMAN, Student, Cornell University; res., 552 Madison Ave., Ithaca, N. Y. Sept. 28, 1906

JOHNSON, HOWARD S., Jeffrey Mfg. Co., 303 Kanawha St., Charleston, W. Va. Mar. 22, 1899

JOHNSON, JASON A., Electrician, Niagara Falls Power Co.; res., 544 10th St., Niagara Falls, N. Y. Sept. 25, 1903

JOHNSON, JOHN C., Electrician, Westinghouse E. & M. Co.; res., 10101 Cumberland S. E., Cleveland, Ohio. Sept. 25, 1903

JOHNSON, MONTGOMERY HUNT, President, Johnson & Morton, 94 Genesee St., Utica, N. Y. Feb. 27, 1903

JOHNSON, WARREN S., Johnson Electric Service Co., 153 Michigan St., Milwaukee, Wis. Sept. 27, 1901

JOHNSON, WOOLSEY MCALPINE, Metallurgist, Tri-Bullion Smelting & Development Co., 43 Exchange Place, New York City. Mar. 28, 1902

JOHNSTON, ANDREW LANGSTAFF, JR., Testing Department General Electric Co., Schenectady, N. Y. Dec. 28, 1906

JOHNSTON, D. MCGREGOR, Electrical Engineer, Jones & Moore, Electric Co., 296 Adelaide St. W., Toronto, Canada. Apr. 22, 1904

JOHNSTON, ELMER LEROY, Switchboard Operator, Milwaukee Electric Railway and Light Co., Milwaukee, Wis. May 14, 1906

JOHNSTON JAMES EWING, Engineer and Superintendent, Mountain Electric Co.; res., 1111 Detroit St., Denver, Colo. Sept. 25, 1903

JOHNSTON, JOHN JOHNSTON HUNTER, Mains Superintendent, Glasgow Corporation Electric Tramways, Glasgow, Scotland. Mar. 24 1905

JOHNSTON, RICHARD HARRY, Advertising Manager, White Sewing Machine Co., 1402 Broadway, New York City. Oct. 24, 1902

JOHNSTON, THOS. J., Counsel in Patent Causes, 11 Pine St., New York City. May 16, 1899

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JOINER, WILLIAM NORVAL, Superintendent, San Marcos Electric Light and Power Co., San Marcos, Texas. Feb. 23, 1906

JOLLY, JOHN MACCALLUM, Electrical Engineer, Noyes Bros., Samson's Building, 75 Barrack St., Perth, Australia. Oct. 24, 1902

JOLLYMAN, JOSIAH PICKARD, Electrician, California Gas and Electric Corporation, Cupertino, Cal. Jan. 27, 1905

JOLY, HENRI LOUIS, Battery Expert and Chemist, The Electromobile Co., Ltd., London, Eng. Feb. 27, 1903

JONES, ALLEN GREEN, Commercial Transformer Department, General Electric Co. Schenectady, N. Y. Mar. 1, 1907

JONES, ARTHUR W., General Electric Co., Schenectady, N. Y. Oct. 17, 1894

JONES, BUDD J., Manager Electric Cal. Dept., Cincinnati Gas & Elec. Co.; res., Ridgeway Apartments, Cincinnati, Ohio. June 15, 1904

JONES, FORREST R., 1702 Melrose Ave., Knoxville, Tenn. May 20, 1890

JONES, GEORGE HARVEY, Assistant Engineer, Chicago Edison Co., 139 Adams St., Chicago, Ill. Dec. 19, 1902

JONES, JOSEPH HENRY, Engineer, Utah Light and Railway Co., 154 Center St., Salt Lake City, Utah. June 21, 1907

JONES, M. E., 7 Lester Ave., Richmond Hill, N. Y. Oct. 27, 1897

JONES, P. N., Pittsburg Railways, Co., Pittsburg, Pa. Mar. 25, 1904

JONES, STERNS FRANCIS, Assistant Electrical Engineer, Postal Telegraph Cable Co., 253 Broadway, New York City. June 21, 1907

JONES, THEODORE INSLEE, Manager, Sales Dept., United Electric Light & Power Co., 1170 Broadway, New York City. Nov. 25, 1904

JONES, WALTER J., Consulting Engineer, with F. A. C. Perrine, 60 Wall St., New York City. May 20, 1902

JORGENSEN, LARS RASMUS, Designing Engineer, with F. G. Baum & Co., 1406 Chronicle Building, San Francisco, Cal. Jan. 27, 1905

JOSEPH, ABRAHAM PINTO, Switchboard Engineer, General Electric Co.; res., 128 Nott Terrace, Schenectady, N. Y. Mar. 29, 1907

JOSEPHI, ROBERT, Chemical Importing and Manufacturing Co., 72 Pine St.; res., 28 W. 95th St., New York City. June 21, 1907

JOSEPH, THEODORE HAROLD, Member of firm, E. J. Electric Installation Co.; res., 205 W. 138th St., New York City. May 17, 1904

JOSLIN, ARBA VANDERBURG, Bay Co., Power Co., Crockett, Cal. Oct. 24, 1902

JOY, WILLIAM MACY, Electrical Engineer, Porto Rico Railway Co., San Juan P. R. Sept. 28, 1906

JOYNER, ALBERT HENRY WINTER, Electrical Engineer, Stone & Webster, 84 State St., Boston, Mass. Sept. 26, 1902

JUDSON, CLARENCE HOWARD, Chief Engineer, Independent Telephone Co., 1115 4th Ave., Seattle, Wash. Sept. 28, 1906

JUDSON, WM. PIERSON, Consulting Engineer, Broadalbin; res., Oswego, N. Y. June 8, 1887

JUHLIN, GUSTAV ADOLF, Assistant Electrical Engineer, Dick Kerr & Co., Ltd., West Strand Road, Preston, Eng. Oct. 23, 1903

KADIC, JOSEPH FRANK, Student, Western Electric Co.; res., 682 S. Avers Ave., Chicago, Ill. May 14, 1906

KAETKER, HENRY, Reliance Electric Mfg. Co., 832 W. 6th St., Cincinnati, O. Feb. 27, 1903

KAHN, MORRIS FREIBERG, Engineer in Cable Department, N. Y. & N. J. Telephone Co., 78 W. 113th St., New York City. May 14, 1906

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KAISER, GEORGE KARL, Engineer, Moore Electrical Co.; res., 107 Halsey St., Newark, N. J. Apr. 28, 1905

KAISER, LOUIS THEODORE, Chief Engineer, Thomas Emery's Sons, Hotel Emery, Cincinnati, O. Apr. 22, 1904

KALENBORN, ARION SIEGFRIED, Asst. Transmission Engineer, with F. G. Baum, Seattle, Wash. Aug. 17, 1904

KAMMERER, JACOB A., General Agent, The Royal Electric Co.; res., 87 Jameson Ave., Toronto, Ont. Apr. 28, 1897

KAPPELLA, ADOLPH SOMERS, Railway Engineering Department, General Electric Co.; res., 132 Park Ave., Schenectady, N. Y. Oct. 24, 1902

KARAPETOFF, VLADIMIR, Asst. Professor of Experimental E. Engineering, Cornell University, Ithaca, N. Y. Feb. 27, 1903

KASUYA, YOHJI, Superintendent of Motive Power, Tokio Densha Tetsudo Co., Tokio, Japan. Oct. 26, 1906

KEAL, JOSEPH, JR., Draughtsman, Industrial Gas Co., Fuller Building, New York City Mar. 29, 1907

KEARNY, PHILIP JOHN, Electrical Department, N. Y., N. H. & H. Rd. Co., New Haven, Conn. Jan. 27, 1905

KEATING, WILLIAM A., Assistant District Superintendent, Allegheny Co. Light Co., Pittsburg, Pa. Jan. 25, 1907

KEBLER, LEONARD, Inspector, Ward Leonard Electric Co., Bronxville, N. Y. Aug. 17, 1904

KEDNEY, LYNN, STEINFORT Electrician in charge of Power House, The Jalapa Railroad and Power Co., Jalapa, Mexico. May 19, 1903

KEEFER, EDWIN S., Supt. of Electric Light Construction, Western Electric Co., 463 West St., New York City. Apr. 18, 1894

KEELER, IRVING PHELPS, Superintendent of Power and Construction, Asheville Electric Co., Asheville, N. C. Nov. 20,1903

KEELER, NELSON BERTRAND, Electrical Engineer, U. S. Engineering Department, 11 West St., New London, Conn. Apr. 26, 1907

KEHOE, MICHAEL J., Chief Electrician, Fort Wayne and Wabash Valley Traction Co., Fort Wayne, Ind. Aug. 25, 1905

KEILEY, JOHN D., Asst. Electrical Engineer, N. Y. C. & H. R. R.R., 5 Vanderbilt Ave., New York City. July 25, 1902

KEILHOLTZ, P. O., Chief Engireer, Consolidated Electric Light & Power Co., Liberty and Lexington Sts., Baltimore, Md. Mar. 21, 1893

KEILY, WILLIAM EUGENE, Managing Editor, *Western Electrician*, 510 Marquette Building, Chicago, Ill. Jan. 29, 1904

KEISER, DAVID L., Erecting Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.; res., Rushville, Ind. Mar. 29, 1907

KEITH, LEIGH SHELTON, Electrical Engineer, New York Telephone Co., 15 Dey St.; res., Hotel San Remo, New York City. May 14, 1906

KELLER, ARTHUR, Engineer, Pawling & Hamischfeger Milwaukee, Wis. Mar. 25, 1904

KELLER, CARL A., Chicago Edison Co., 139 Adams St., Chicago, Ill. Sept. 27, 1901

KELLER, E. E., Vice-president and General Manager, Westinghouse Machine Co., Pittsburg, Pa. Sept. 20, 1893

KELLEY, FREDERICK WILLIAMS, Vice-president and General Manager, Helderberg Cement Co., 78 State St., Albany, N. Y. Nov. 24, 1905

KELLEY, WALTER STUART, Chief Engineer, Holtzer-Cabot Electric Co., Brookline. Mass. Oct. 28, 1904

KELLOGG, JAMES GIFFORD, 5001 Woodlawn Ave., Chicago, Ill. Nov. 20, 1903

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KELLOGG, JAMES W., *M.E.*, Manager, Marine Sales, General Electric Co.; res., 10 Front St., Schenectady, N. Y. June 26, 1891

KELLEY, JOHN, Understudy Salesman, Westinghouse Electric and Mfg. Co., 1738 N. 16th St., Philadelphia, Pa. Sept. 28, 1906

KELLY, JOHN WESLEY, JR., General Superintendent, General Acoustic Co., 1265 Broadway, New York City. Dec. 18, 1903

KELLY, THOMAS FRANCIS, Electrical Engineer, Oregon Water Power & Railway Co., Portland, Ore. Dec. 18, 1903

KELSAY, G. H., Superintendent Power, Indiana Union Traction Co., Anderson, Ill. Aug. 25, 1905

KEMBLE, PARKER HENRY, President and General Manager, Northern Conn. Light and Power Co., Windsor Locks, Conn. Mar. 1, 1907

KEMPTON, WILLIARD HOYT, Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 1, 1907

KENDALL, HOWARD CONVERSE, Contract Department, Allis-Chalmers Co., Milwaukee, Wis. Nov. 23, 1906

KENDALL, WILLIAM ROY, Consulting Electrical Engineer, Weeks and Kendall, 605 New Nelson Bldg., Kansas City, Mo. Apr. 26, 1907

KENNEDY, A. P., Electrical Engineer, Yates, Tallapoosa Co., Ala.
[Life Member.] Apr. 26, 1899

KENNEDY, JEROME DOUBLEDAY, Telephone Engineer, Western Electric Co., 259 So. Clinton St., Chicago, Ill. Apr. 27, 1906

KENNEDY, JOSEPH B., In chief Engineers Office, Department of Water Supply, Gas and Electricity, New York City. Aug. 25, 1905

KENNEDY, MATTHEW G., United Gas Improvement Co., Broad and Arch Sts., Philadelphia, Pa. Apr. 28, 1905

KENT, JAMES, Salesman, Fort Wayne Electric Works, 812 Empire Building, Pittsburg, Pa. Dec. 23, 1904

KENT, JAMES MARTIN, Instructor in Steam and Electricity, Manual Training High School, Kansas City, Mo. July 26, 1900

KENT, WALTER, Inspector, Fort Wayne Electric Works, 529 W. Jefferson St., Fort Wayne, Ind. Sept. 28, 1906

KENYON, ALAN DOUGLAS, Patent Counsel, Kenyon & Kenyon, 49 Wall St.; res., 351 W. 141th St., New York City. Apr. 22, 1904

KENYON, BLYDON ELLERY, Instructor in Electrical Engineering, University of Texas, Austin, Tex. Feb. 23, 1906

KENYON, MAXWELL S., Chief Assistant, Traction Department, Br. Westinghouse Co. Ltd., Trafford Park, Manchester, Eng. Jan. 25, 1907

KENYON, OTIS ALLEN, McGraw Publishing Co., 239 W. 39th St.; res.,542 W. 159th St., New York City. May 14, 1906

KENYON, WILLIAM HOUSTON, Patent Laywyer, 49 Wall St.; res., 321 W. 82d St., New York City. Apr. 22, 1904

KER, W. WALLACE, Instructor of Electricity, Hebrew Technical Institute, 36 Stuyvesant St., New York City. Sept. 25, 1895

KERINS, JOHN STEWART, Student, Brooklyn Polytechnic Institute, Brooklyn; res.,993 Summit Ave., New York City. Apr. 26, 1907

KERN, OSCAR FREDERICK, Station Attendant, Mt. Whitney Power Co., Three Rivers, Cal. July 19, 1904

KERN, WALTER EVERETT, Inspector, Electrical Department, District of Columbia; res., 29 R St., N. W., Washington, D. C, Apr. 28, 1905

KERNOT, WILFRID NOYCE, Instructor, Technical College, Latrobe St., Melbourne, Australia. Feb. 24, 1905

KERR, DAVID J., Electrician, Champion Fiber Co., Canton, N. C.
June 21, 1907

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KERR, SAMUEL ROSS, 1522 1st Nat. Bank Bldg., Chicago, Ill. Jan. 3, 1902

KERR, WALTER C., President, Westinghouse, Church, Kerr & Co., 12 Bridge St., New York City. Jan. 25, 1907

KERSHNER, JEFFERSON E., Consulting Engineer, The Lancaster County R. & L. Co., 445 W. Chestnut St., Lancaster, Pa. Jan. 3, 1902

KETTERING, CHARLES FRANKLIN, Director of Electrical Inventions, National Cash Register Co., Dayton, O. June 15, 1904

KEYES, CLIFT BUTTON, Erecting Engineer, General Electric Co., Schenectady, N. Y. July 28, 1903

KEYES, FREDERICK A., Sales Engineer, American Steel and Wire Co., 24 State St., New York City. Mar. 29, 1907

KIDDER, HARRY ALVIN, Ass't. Elec. Super., Interborough Rapid Transit Co., 59th St.and 11th Ave., New York City.Nov. 23, 1906

KIDDER, LEE HOBART, Pittsburg & Butler Ry., Co., Butler Pa. Oct. 28, 1904

KIDDLE, ALFRED W., Partner, Redding, Kiddle and Greeley; res., 314 West 98th St., New York City. Jan. 27, 1905

KIEFER, CARL JACKSON, Reliance Engineering Co., 312 Fourth National Bk. Bldg., Cincinnati, Ohio. Aug. 17, 1904

KIER, SAMUEL MARTIN, President, Kier Fire Brick Co., 341 6th Ave.; res., 5820 Callowhill St., Pittsburg, Pa. Jan. 24, 1902

KILBOURNE, COVINGTON GUION, Student, Columbia University; res., 357 West 115th St., New York City. Mar. 24, 1905

KIMBALL, EDWIN ELLIOTT, Railway Engineering Department, General Electric Co.., Schenectady, N. Y. Dec. 28, 1906

KIMBALL, FRED MASON, Manager, Small Motor Department, General Electric Co., 84 State St., Boston, Mass. Apr. 23, 1903

KIMBALL, ROGER NELSON, Vice-president and Supt., Kenosha Gas and Electric Co., 210 Wisconsin St., Kenosha, Wis. Nov. 20, 1903

KIMBALL, WILLIAM FRANCIS, Assistant to F. C. Sargent, Malden Electric Co., 101 Linden Ave., Malden, Mass. July 26, 1907

KIMBER, WILLIAM MARMADUKE COPE, Instrument Inspector, Leeds and Northrup Co., Philadelphia, Pa. Mar. 1, 1907

KING, ARTHUR CHARLES, Engineer, Northern Electric Mfg. Co., Madison, Wis. Nov. 20, 1903

KING, EDWARD DENNISON, Chief Operator, Ontario Power Co., Niagara Falls South, Ont. Sept. 22, 1905

KING, HARRY DEGOLIER, Supt., Public Service Corporation of N. J., 14th and Bloomfield Sts., Hoboken, N. J. July 19, 1904

KING, HARRY R., [*Local Secretary*], Electrical Engineer, Western Electric Co., Hawthorn; res., Hinsdale, Ill. Nov. 22, 1901

KING, MORLAND, Instructor, Electrical Engineering, Union College, Schenectady, N. Y. Nov. 23, 1906

KING, R. O., North Tonawanda, N.Y. Sept. 26, 1903

KINGSBURY, JOHN MCLEAN, Electrical Engineer, Switchboard Department, Allis-Chalmers Co., Milwaukee, Wis. Apr. 27, 1906

KINNECOM, FRED ORRIN, General Manager, Electrical Department, Charles S. Bush Co., Providence, R. I. May 19, 1903

KINNEY, CLARENCE WALTER, Electrical Engineer, Page Electric Co., 24 Pearl St.; res., Olean St., Worcester, Mass. Feb. 24, 1905

KINNEY, FRANK FAIRCHILD, Engineer Testing Laboratory, Chicago Edison Co., 84 Market St., Chicago, Ill. Apr. 28, 1905

KINNEY, GEORGE IRVING, B. L. Grow Realty Co. San Mateo, Cal. Sept. 28, 1906

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KINSLEY, CARL, Assistant Professor of Physics, University of Chicago, Chicago, Ill. May 18, 1897

KINTNER, CHARLES JACOB, Solicitor of Patents and Expert, 45 Broadway; res., 36 E. 29th St., New York City. Feb. 28, 1902

KIRK, GEORGE ELLIS, [*Local Secretary*] Patent Lawyer, 1614 The Nichols; res., 2118 Erie St., Toledo, O. Apr. 27, 1906

KIRKER, GAYLORD BRENNAN, Societé Anonyme Westinghouse; res., 2 Boulevard Sadi Carnot, Lé Havre, France, Oct. 23, 1903

KIRCHER, HARRY BERTRAM, Manager, Belleville Gas and Electric Co., Belleville, Ill. Mar. 1, 1907

KIRKLAND, H. B., National Metal Moulding Co., Fulton Building, Pittsburg, Pa. Sept. 28, 1906

KISHI, KEIJIRO, Chief Engineer, Shibaura Engineering Works No. 1. Shinhamacho, Kanosugi Shibaku, Tokyo, Japan. Dec. 18, 1903

KITTLER, DR. ERASMUS, Professor at the Technical High School, Darmstadt, Germany. Dec. 16, 1896

KITTELBERGER, JOHN B., Chief of Maintenance, Central District and Printing Telegraph Co.; res., 416 7th Ave., Pittsburg, Pa. Mar. 29, 1907

KLAUDER, RUDOLPH H., Electrical Engineer, General Storage Battery Co., Boonton, N. J. Aug. 13, 1897

KLEIN, RICHARD M., Engineering Dept., Northern Electrical Mfg. Co., Madison, Wis. July 28, 1903

KLINE, JAMES JOSEPH, Engineer, Ft. Wayne Electric works, Ft., Wayne, Ind. Jan. 3, 1902

KLIPPHAHN, EMIL OSWALD ERNEST, Davenport, Light & Power Co., 301 Pacific Ave., Santa Cruz, Cal. Apr. 23, 1903

KLOCK, RAYMOND A., Assistant Electrical Engineer, the U. S. Signal Corps, Signal Office, Washington, D. C. Mar. 27, 1903

KLOMAN, THEODORE W., Manager and Treasurer, The John F. Kelly Engineering Co., 149 Broadway, New York City. June 19, 1903

KLUMPP, JOHN BARTLEMAN, Inspecting Engineer, The United Gas Improvement Co., Philadelphia, Pa. Dec. 19, 1902

KNAUR, RICHARD I., Director, Felten and Guilleaume, A. G. X. Guidrunstrasse 11, Vienna, Austria. June 21, 1907

KNAPP, MORRIS JASEN, Road Engineer, Westinghouse Electric & Mfg., Co., 1107 Traction Building, Cincinnati, Ohio. Jan. 25, 1907

KNEY, OTTO, Manager Advertising Department, Northern Electrical Mfg. Co.; res., 128 E. Johnson St., Madison, Wis. July 28, 1905

KNIGHT, CARL DUNHAM, Instructor, Worcester Polytechnic Institute, Worcester, Mass. Nov. 24, 1905

KNIGHT, CHARLES D., General Electric Co., Schenectady, N. Y. May 15, 1905

KNIGHT, CLIMPSON MOORE, General Manager, Idanha Machine Co., Whitehall Bldg., New York City. Apr. 23, 1903

KNIGHT, PERCY HENRY, Flat 8, Cor. Coal & Rebecca Sts., Wilkinsburg, Pa. Mar. 28, 1902

KNIGHT, SEYMOUR, Electric Bond & Shares Co., 62 Cedar St., New York City. May 19, 1903

KNIGHT, THOMAS SAWYER, Erecting Engineer, 25 No. Ferry St., Schenectady, N. Y. Mar. 24, 1905

KNIPP, CHARLES TOBIAS, Assistant Professor of Physics, University of Illinois; res., 502 W. Illinois St., Urbana, Ill. Dec. 15, 1905

KNOPF, CARL LAFAYETTE, Machinist, E. E. Lab., Ohio State University; res., 1535 E. Main St., Columbus, O. Jan. 26, 1906

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KNOX, FRANK H., Chief Engineer, Boise & Interurban Railway Co., Boise, Idaho. June 20, 1894

KNOX, GEO. W., President, Knox Engineering Co., 1409 Fisher Building, Chicago, Ill. Nov. 18, 1896

KNOX, HARRY HAMILTON, Electrical Engineer, John J. Sesnon Co., Nome, Alaska. Jan. 27, 1905

KNOX, S. L. G., Manager and Chief Engineer, Bucyrus Co., South Milwaukee, Wis. Nov. 23, 1898

KOBAYASHI, WADACHI, Superintendent, Kanazawa Elec. Co., Shimohonda-machi, Kanazawa, Kaga, Japan. Oct. 26, 1906

KODAMA, HAYADZUCHI, Chief Engineer, Tokyo Railway Co., 3 Urakucho Sanchome Kojimachi Ku, Tokyo, Japan. July 25, 1902

KODJBANOFF, BASIL GEORGE, Illuminating Engineer, Benjamin Electric Mfg. Co., New York City. May 17, 1904

KOENIG, DAVID, Engineer, Western Electric Co.; res., 1 Manhattan Ave., New York City. Mar. 1, 1907

KOESTER, FRANK, Designing Engineer, J. G. White & Co.; res., 213 W. 81st St., New York City. Mar. 29, 1907

KOGI, TORAJIRO, Consulting Engineer, Kurumaya-Cho, Nijo, Kyoto, Japan. June 19, 1903

KOHLER, ALBERT JOSEPH, Chief Engineer, Lynchburg Traction and Light Co., 601 Church St., Lynchburg, Va. Aug. 17, 1904

KOHLER, L. FRANK, Student, Columbia Universtiy; res., 362 Cypress Ave., New York City. Nov. 25, 1904

KOHN, NATHAN, P-K. Engineering Co., 1118 Chemical Building, St. Louis, Mo. Apr. 28, 1905

KONISHI, TAMENOSUKE, Electrical Engineer, Mitsui & Co., 445 Broome St., New York City. Sept. 25, 1903

KORST, PHILIP HAROLD, Secretary and Manager, Janesville Electric Co., Janesville, Wis. June 19, 1903

KOS, DIRK, 60 Clark St., Brooklyn, N. Y. June 21, 1907

KOUSNETZOFF, W. A., Mining Engineer, Vladivostock, East Siberia. Aug. 22, 1902

KOUWENHOVEN, WILLIAM BENNETT, Assistant in Physics, Polytechnic Institute; res., 8 Kouwenhoven Pl., Brooklyn, N. Y. Dec. 28, 1906

KRAEUCHI, JOHN ADOLPH, Emerson Electrical Mfg. Co.; res., 1241 Blackstone Ave., St. Louis, Mo. July 28, 1905

KRAMER, XAVIER A., Magnolia Electric Light and Power Co., Magnolia, Miss. Aug. 17, 1904

KRANTZ, HUBERT F., President and Treasurer, H. Krantz Mfg. Co., 160 7th St.; res., 610 11th St., Brooklyn, N. Y. Feb. 26, 1904

KRASS, RALPH WILLIAM, Westinghouse, Church, Kerr & Co., 10 Bridge St.; res., 320 E. 57th St., New York City. Sept. 28, 1906

KRATZ, ARTHUR BRYSON, Consulting Telephone Engineer, Elyria, O. Dec. 18, 1903

KREIDLER, W. A., Editor and Publisher, *Western Electrician*, 510 Marquette Building, Chicago, Ill. Oct. 4, 1887

KRETSCHMER, EDWARD E., Chief Clerk to General Superintendent, Chicago & Oak Park Elevated R.R., Chicago, Ill. Sept. 28, 1906

KROGER, FRED HUTTON, Instructor, Cornell University, Ithaca, N. Y. Dec. 23, 1904

KROHN, SIGVALD, Electrical Engineer, A. E. G., Bahnabteiling, Freidrich Carl Ufer 2-4, Berlin, Ger. July 28, 1903

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KRUESI, AUGUST H., Designing Engineer, General Electric Co.; res., 225 Union St., Schenectady, N. Y. Jan. 9, 1901

KRUESI, PAUL JOHN, Manufacturer, Secretary and Treasurer, American Lava Co., Chattanooga, Tenn. Oct. 25, 1901

KRUMM, LOUIS RALPH, Assistant Electrical Engineer, U. S. Signal Service at Large, Army Building, New York City. Mar. 23, 1906

KUBIERSCHKY, MARTIN TRAUGOTT AUGUST, Street Railway Director, Berlin W. 30 Habsburgerstr 11, Ger. Dec. 18, 1903

KUMPE, KARL BARCLAY, Locating Engineer, C. M. & S. H. P. Ry., Hoquian, Wash. Sept. 28, 1906

KUNIYASU, UICHI, Test Man, General Electric Co., Schenectady, N. Y. Jan. 25, 1907

KUNZE, RUDOLPH I., Electrical Engineer, Otis Elevator Co.; res., 17 Culver St., Yonkers, N. Y. Nov. 20, 1903

KYNOCH, JAMES, Chief Engineer, Canadian General Electric Co., 14 King St. E., Toronto, Ont. Apr. 23, 1903

KYSER, HENRY HEARST, Engineer, Talladega Plannig Mill and Lumber Co., Talladega, Ala. June 21, 1907

LACIAR, BERT ERWIN, District Inspector, New York & New Jersey Telephone Co., Newark, N. J. Mar. 1, 1907

LACOMBE, CHARLES FREDERICK, Chief Engineer of Light and Power, City of New York; res., University Club, New York City. Mar. 23, 1906

LACOUNT, HENRY OSGOOD, Electrical Inspector, Mutual Fire Insurance Co., Boston, Mass. Feb. 24, 1905

LA FEVER, CHARLES A., Assistant Superintendent and Electrical Engineer, Advance Thresher Co., Battle Creek, Mich. Sept. 25, 1903

LAFORE, JOHN ARMAND, Electrical Engineer, 119 So. 11th St.; res., Bala, Pa. May 15, 1900

LAILE, WALTER, Erecting Engineer, Triumph Electric Co.; res., 415 Fairview Ave., Cincinnati, O. Apr. 23, 1903

LAKE, EDWARD N., Engineer, The Arnold Co., 181 La Salle St., Chicago, Ill. Apr. 23, 1903

LAMB, RICHARD, Consulting, Civil and Electrical Engineer, 136 Liberty St., New York City. Dec. 18, 1895

LAMBERT, CARL FRED, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 29, 1907

LAMME, WILLIAM FENNER, Construction Department, Westinghouse E. & M. Co., San Francisco, Cal. May 17, 1904

LANCASTER, WILLIAM CARRINGTON, Electrical Engineer, United Engineering and Contracting Co., New York City. Sept. 28, 1906

LAND, FRANK, *M.E.*, Land-Wharton Co., 910 Pennsylvania Building, Philadelphia, Pa. Sept. 22, 1891

LANDERS, GEORGE FOREMAN, Captain Artillery Corps, Fort Hamilton, N. Y. Nov. 20, 1903

LANDON, EDWIN, Instructor, Department of Electricity, School of Submarine Defense, Fort Totten, N. Y. Jan. 25, 1907

LANE, EMMETT HORACE, Assistant, H. F. Blackwell, Department of Water Supply; res., 4422 18th Ave., Brooklyn, N. Y. June 21, 1907

LANE, HAROLD BOUCK, Testing Department, General Electric Co., Schenectady, N. Y. Mar. 1, 1907

LANG, ARTHUR GORDON, American Telephone & Telegraph Co.; res., 409 W. 117th St., New York City. Sept. 25, 1903

LANG, EDMUND, Purchasing Agent, Wheeler Condenser and Engineering Co., West St. Building, New York City. Feb. 27, 1903

LANG, GEORGE STUART, Engineer, Electric Storage Battery Co., Wainwright Building, St. Louis, Mo. Jan. 23, 1903

LANGAN, JOHN, Salesman,, Okonite Co., 253 Broadway, New York City. July 19, 1904

LANGDELL, JOSEPH CHESTER, Meter Expert, Hudson River Power Co.; res., 28 Chestnut St., Albany, N. Y. June 21, 1907

LANGWORTHY, ROSS ANDREW, Engineer, Ford, Bacon & Davis, 331 Third Ave. North, Nashville, Tenn. Aug. 25, 1905

LANIER, ALEXANDER CARTWRIGHT, [*Local Secretary*] Assistant Professor of E. E. University Cincinnati, Cincinntia O., Mar. 25, 1904

LANMAN, WILLIAM H., Board of Patent Control, 120 Broadway, New York City. June 6, 1893

LANPHIER, ROBERT CARR, Superintendent and Electrician, Sangamo Electric Co., Springfield, Ill. Nov. 22, 1901

LANSINGH, VAN RENSSELAER, Electrical Engineer, 227 Fulton St., New York City. Aug. 23, 1899

LANSLEY, WILLIAM J., General Manager, Hudson & Middlesex Telephone Co., Perth Amboy, N. J. Apr. 23, 1903

LA PORTE, NORBERT M., Electrical Engineer, Atlantic Mills; res., 410 Broadway ,Providence, R. I. Feb. 23, 1906

LARKE, WILLIAM JAMES, Manager, Power and Mining Dept., British Thomson-Houston Co., Ltd., Rugby, Eng. Sept. 25, 1903

LARKIN, FRED V., Engineer, Telluride Power Co., Ames, Colo. Apr. 26 1907

LARRABEE, HAROLD DAVIS, Superintendent, Hoosick Falls Illuminating Co., Hoosick Falls, N. Y. May 14, 1906

LASHER, ALBERT C., Erecting Department, Westinghouse Electric and Mfg. Co., Candler Building, Atlanta, Ga. Sept. 28, 1906

LATEY, HENRY NELSON, Engineer, Latey & Slater, 100 Broadway, New York City. June 15, 1904

LATHAM, HARRY MILTON, with American Steel and Wire Co., Worcester, Mass. Dec. 16, 1896

LATHROP, LEIGH HUNT, Foreman, Electrical Testing Bureau, Milwaukee Electric Railway and Light Co., Milwaukee, Wis. Mar. 29, 1907

LATOUR, MARIUS CHARLES ARTHUR, Electrical Engineer, 22 Rue de Tocqueville, Paris, France. June 19, 1903

LATTA, EDWARD DILWORTH, JR., Superintendent, Charlotte Electric Railway Light and Power Co., Charlotte, N. C. July 28, 1905

LATTA, JAMES EDWARD, Associate Professor of Physics, University of North Carolina, Chapel Hill, N. C. Aug. 25, 1905

LAUBERSTEIN, JACOB ALEXANDER, Assistant in Testing Laboratory, Public Service Corporation, 83 Court St., Newark, N. J. Apr. 28, 1905

LAUDENBERGER, ERNEST C., Student Apprentice, General Electric Co.; res., 60 Commercial St., West Lynn, Mass. Mar. 29, 1907

LAURIE-WALKER GEORGE LIVINGSTON, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. May 19, 1903

LAVERGNE, JEAN, Technical Director, Cantono Electric Tractor Co., Boyden and Nassau Sts., Newark, N. J. Jan. 29, 1904

LAWLER, JUSTUS CLAUDE, Assistant, Colorado Springs Electric Co., 107 East Kiowa, Colorado Springs, Colo. Dec. 18, 1903

LAWRENCE, ARTHUR BURTIS, Assistant, C. D. Haskins, General Electric Co.; res., 36 University Place, Schenectady, N. Y. Nov. 23, 1906

LAWRENCE, RALPH RESTIEAUX, Assistant Professor E. E., Massachusetts Institute of Technology, Boston, Mass. May 15, 1905

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LAWRENCE, WM. G., Manager, Light and Power Department, Reading Mass. Feb. 28, 1900

LAWRENCE, W. H. Assistant Superintendent, Waterside Station, The N. Y. Edison Co., 38th St. & 1st. Ave., New York. Apr. 26, 1899

LAWS, FRANK ARTHUR, Associate Professor of Electrical Testing, Massachusetts Institute of Technology, Boston, Mass. May 14, 1906

LAWSON, CHARLES SHELLEY, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Sept. 28, 1906

LAWSON, GEORGE, General Electric Co.; res., 5 So. Church St., Schenectady, N. Y. Nov. 24, 1905

LAWSON, JAMES T., Assistant to Superintendent, United Electric Co., of N. J., 14th and Bloomfield Sts., Hoboken, N. J. Aug. 22, 1902

LAWTON, ARTHUR HAMILTON, Assistant Electrical Engineer, New York Edison Co., 55 Duane St., New York City. May 19, 1903

LAWTON, EDWIN FRANKLIN, Superintendent Hartford Electric Light Co.; res., 43 Deerfield Ave., Hartford, Conn. Sept. 25, 1903

LAWTON, FRANCIS N., Manager, Huntsville Railway and Light Co., Huntsville, Ala. May 19, 1903

LAWTON, JOHN HENRY, Humboldt Electric Light & Power Co., Humboldt, Iowa June 15, 1904

LAXTON, FRED MITCHELL, Electrical Mfg. & Equipment Co., Atlanta, Ga. Mar. 25, 1904

LAXTON, RALPH ROBERTS, Westinghouse Electric and Mfg. Co., 605 Trust Building, Charlotte, N. C. Mar. 25, 1904

LAYTON, GORDON, Electrical Engineer, British Westinghouse E. & M. Co.; Trafford Park, Manchester, Eng. Jan. 3, 1902

LEA, EDWARD S., Sales Manager, DeLaval Steam Turbine Co., Trenton, N. J. May 17, 1904

LEAR, JOHN EMERY, Department of Physics, Agriculture & Mechanical College of Texas, College Station, Texas. Apr. 23, 1903

LEARY, JOHN JOSEPH, Electrical Engineer, Marconi Wireless Telegraph Co., 27 William St., New York City. Apr. 23, 1903

LEASE, LEONARD JOHN, Draftsman, Western Elec Co.; res., 918 N. 41st Court, Chicago, Ill. Oct. 26, 1906

LEAVITT, ROBERT PABODY, Electrical Engineer, Albany and Hudson Railroad Co., Hudson, N. Y. June 19, 1903

LEBENBAUM, PAUL, Draftsman, Southern Pacific Co., 1117 Flood Building, San Francisco, Cal. July 19, 1904

LEBLANC, MAURICE, Consulting Electrical Engineer, Le val sur Seine, Croissy, France. Apr. 25, 1902

LECLEAR, GIFFORD, Electrical and Mechanical Engineer, Partner Densmore & LeClear, 15 Exchange St., Boston, Mass. Oct. 27, 1897

LEDOUX, A. R., *M.S.*, *Ph.D.*, President, Ledoux & Co. (Inc), 99 John St.; res., 39 W. 50th St., New York City. Dec. 7, 1886

LEDWARD, HUGH, Engineer, Dick, Kerr & Co., Ltd., Abchurch Yard, Cannon St., London E. C., Eng. Jan. 29, 1904

LEE, ALBERT W., Manager, Concord Municipal Light Plant, Concord, Mass. Apr. 23, 1903

LEE, CAZENOVE GARDNER, JR., Student, Cornell University; res., 1½ Central Ave., Ithaca, N. Y. Dec. 28, 1906

LEE, CHARLES EUGENE, Engineer and Salesman, Electric Gas Lighting Co., 115 Purchase St., Boston, Mass. July 28, 1903

LEE, CLAUDIUS, Instructor in Electrical Engineering, Virginia Polytechnic Institute, Blacksburg, Va. Mar. 23, 1906

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LEE, JOHN C., Chemist and Electrician, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Mar. 18, 1890

LEE, THOMAS FREDERICK, Telephone Engineer, Western Electric Co., No. Woolwich, London E., England. Mar. 1, 1907

LEEDS, MORRIS EVANS, President, The Leeds & Northrup Co., 4901 Stenton Ave.; res., 3221 N. 17th St., Philadelphia, Pa. Apr. 26, 1901

LEEDS, NORMAN, Electrical Engineer, Bridgeport Malleable Iron Co., Bridgeport, Conn. Feb. 28, 1901

LEGE, FRED MERION, JR., General Manager, Brush Electric Lt. & Power Go., Galveston, Texas. Dec. 15, 1905

LEGRAND, CHARLES, Copper Queen Consolidated Mining Co., 99 John St., New York City. Jan. 23 1903

LEHDER, WALTER MAX, General Electric Co., 44 Broad St., New York City. Mar. 29, 1907

LEHOSE, FRANCIS MAC, Regulator, New York Edison Co., 151 E. 39th St., New York City. June 21, 1907

LEHR, EDWIN E., Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Apr. 27, 1906

LEIGHTON CLIFFORD HENRY, Chief Electrician, Saco and Pettee Machine Co., Boston. Mass. June 21, 1907

LEIST, WILLIAM, Member and Constructing Engineer, Jantz and Leist Elec. Co., 808 Elm St., Norwood, Cincinnati, O. Mar. 27, 1903

LEITCH, HOWARD WALLACE, Switchboard Regulator, The New York Edison Co., 38th St. & First Ave., New York City. Nov. 23, 1898

LEITCH, JOHN INGRAM, Manager Albernee Stone Co., 54 N. Clinton St., Chicago; res., 307 Davis St., Evanston, Ill. Feb. 26, 1904

LELAND, GEORGE BENTON, Superintendent, Stamford Gas and Electric Co., Stamford, Conn. Apr. 26, 1907

LEMMON, GEORGE NELMS, Sanderson & Porter, 323 Baronne St., New Orleans, La. June 15, 1904

LENNARD, WILLIAM HENRY, Electrical Engineer, Houghton Elevator and Machine Co.; res., 1334 Fitchland Ave., Toledo, O. June 21, 1907

LESLEY, HUGH, Engineer, The Electric Storage Battery Co., 19th St. and Allegheny, Ave., Philadelphia, Pa. Sept. 26, 1902

LESLIE, EDWARD ANDREW, Student Polytechnic Institute; res., 262 Hancock St., Brooklyn, N. Y. Dec. 28, 1906

LESTER, BERNARD, Assistant Industrial and Power Department, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Sept. 28, 1906

LESTER, WILLIAM JUNIUS, Chief Engineer Anthony Shoals Power Co., Washington, Ga.; res., Fredonia, N. Y. Oct. 26, 1906

LETHEULE, PAUL, Consulting Engineer, 5 Rue Clauzel, Paris, France. May 17, 1898

LE TOURNEAU, EDWARD HAROLD, Tester, N. Y. C. & H. R. R. R. Co., Port Morris Power Station, New York City. July 26, 1907

LEVY, LEHMAN, Construction Supt., Schwarzschild & Sulzberger Co., 41st St. and Ashland Ave., Chicago, Ill. Apr. 23, 1903

LEVY, MAX J., Electrical Contractor, Edwards Electrical Construction Co. 39 East 42d St., New York City. Feb. 26 1904

LEWIN, ARTHUR WYNDHAM, Dilzell Engineering & Construction Co., 739 Poydras St., New Orleans, La. Aug. 25, 1905

LEWINSON, LEONARD JULIAN, 129 E. 95th St., New York City. July 19, 1904

LEWIS, EMANUEL WILLIAM, 1320 So. State St., Syracuse, N. Y. Nov. 20, 1903

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LEWIS, GEORGE, Construction Superintendent, J. G. White & Co., San Juan Light & Transit Co., San Juan, P. R. Sept. 28, 1906

LEWIS, HARRY B., Division Line Foreman, Central Union Telephone Co.; res., The Delano, Indianapolis, Ind. Mar. 1, 1907

LEWIS, ISAAC NEWTON, Instructor, Department Electricity, U. S.. Artillery School, Fort Monroe, Va. June 21, 1907

LEWIS, JOSEPH FRAZIER, Technical Assistant, General Electric Co.; res., 20 So. Common St., Lynn, Mass. Jan. 27, 1905

LEWIS, MORGAN MILES, Cement, Cal. Oct. 26, 1906

LEWIS, THEODORE, Electrician and Chief Operator, F. J. G. Sub-station, Amsterdam, N. Y. Mar. 1, 1907

LIBBEY, JOSEPH HAROLD, Stone & Webster Engineering Corp., 84 State St., Boston, Mass. Apr. 27, 1906

LIBBY, ALBION DANA TOPLIFF, Engineer, Dean Electric Co.; res., 230 E. 8th St., Elyria, O. Feb. 26, 1904

LICHTENBERG, J. CHESTER, ALAN ARTHUR, Testing Department, General Electric Co., Schenectady, N. Y. Jan. 27, 1905

LIDDERDALE, ARTHUR HECTOR, Westinghouse Bldg., Norfolk St., Strand, London, Eng. May 19, 1903

LIDE, MARTIN JAMES, Consulting Electrical Engineer, Birmingham, Ala. Mar. 29, 1907

LIDE, THOMAS NORWOOD, Westinghouse Electric and Mfg. Co., Pittsburg; res., 403 Gray Bldg., Wilkinsburg, Pa. Nov. 23, 1906

LIEBERMANN, PAUL B., Assistant Electrical Engineer, Sprague Electric Co., Bloomfield, N. J. Mar. 29, 1907

LIGHTHIPE, WILLIAM WILSON, Otis Elevator Co., 17 Battery Place, New York City. July 19, 1904

LIGON, WILLIAM DANIEL, Electrical Engineer, Westinghouse Electric and Mfg. Co., University Building, Syracuse, N. Y. June 19, 1903

LILLIBRIDGE, RAY D., 170 Broadway, New York City. Jan. 24, 1902

LINCOLN, EDWIN STODDARD, Electrical Engineer, Chas. J. Jager Co., 281 Franklin St., Boston, Mass. Sept. 28, 1906

LINCOLN, FREDERICK H., Supt. Lines and Cables, Philadelphia Rapid Transit Co., 820 Dauphin St., Philadelphia, Pa. May 15, 1905

LINCOLN, JOHN CROMWELL, President, Lincoln Electric Co., 49 Wood St., Cleveland, O. Mar. 1, 1907

LIND, EMILE G., Engineer, Tudor Storage Battery Export Syndicate, Milton House, Surrey St., Strand, London, Eng. Feb. 26, 1904

LINDALL, JOHN, Superintendent Motive Power and Machinery, Boston Elevated Ry. Co., 439 Albany St., Boston, Mass. Apr. 27, 1906

LINDBERG, FRITZ ALBIN, Assistant Electrical Engineer, with George M. Brill, 5832 Indiana Ave., Chicago, Ill. Mar. 25, 1904

LINDEMANN, PETER, Engineer, Erecting Dept. Westinghouse Electric & Mfg. Co., 1211 Story St., Boone, Iowa. June 14, 1905

LINDMAN, GUSTAV, Chief Draftsman, St. Louis Transit Co., St. Louis, Mo., res. Stockholm, Sweden. May 19, 1903

LINDQUIST, DAVID LEONARD, Otis Elevator Co., res., 205 Warburton Ave., Yonkers, N. Y. Aug. 17, 1904

LINDRIDGE, CHARLES DOUGLAS, 7 West 65th St., New York City. Nov. 23, 1906

LINDSAY, ROBERT, General Supt., The Cleveland Elec. Ill. Co., 717 Cuyahoga Building, Cleveland, Ohio. Apr. 27, 1898

LINDSTROM, ALBERT STEWART, Western Electric Co.; res., 111 Field St. Dallas, Tex. Aug. 17, 1904

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LINDSTROM, KARL ARVID, Electrical Engineer, Stocksund, Sweden. Jan. 23, 1903

LINEBAUGH, FRANK W., Supt. and Manager, Ames Municipal Electric Light and Water Works, Ames, Iowa. Aug. 17, 1904

LINEBAUGH, JESSE JOSEPH, Engineer, Railway Engineering Department, General Electric Co., Schenectady, N. Y. Nov. 23, 1906

LINZEE, ALBERT CARL, Designing Engineer, Akron Electric Mfg. Co., Akron, Ohio. Feb. 27, 1903

LISBERGER, SYLVAN JOSEPH, Electrical Engineer, California Gas & Electric Corporation, 925 Franklin St., San Francisco, Cal. May 15, 1905

LISLE, ARTHUR BEYMER, General Representative, Narragansett Electric Lighting Co., Providence; res., East Greenwich, R. I. Jan. 9, 1901

LISTON, JOHN, Sales Department, Stanley G. I. Electric Mfg. Co., Pittsfield, Mass. Apr. 27, 1906

LITTLE, CLARENCE DUANE, Tester, Westinghouse Electric and Mfg. Co., Newark; res. 157 Walnut St., Montclair, N. J. June 21, 1907

LITTLE, C. W. G., Engineering Manager, The British Electric Traction Co., Ltd., Donington House, Norfolk St., London, Eng. Apr. 22, 1896

LITTLE, JOE WILSON, President, Carter & Gillespie Electric Co., 40 N. Broad St.; res., 82 Oak St., Atlanta, Ga. Mar. 25, 1904.

LITTLEFIELD, LEMUEL, JR., Engineering Department, Gould Storage Battery Co., 341 Fifth Ave., New York City. Jan. 29, 1904

LIVERS, JOHN LEO, Electrical Engineer, Grottoes, Va. Oct. 24, 1902

LIVINGSTON, JOHNSTON, JR., The United Engineering and Contracting Co., 113 East 22d St., New York City. May 17, 1898

LIVSEY, J. H., Salesman and Manager Detroit Office, General Electric Co., 1440 Majestic Building, Detroit, Mich. Apr. 25, 1900

LLOYD, EDWARD WILLIAM, Assistant Superintendent of Construction, Chicago Edison Co., 139 Adams St., Chicago. Feb. 28, 1902

LLOYD, WILLIAM JOHN, 37 Hillmorton Road, Rugby, Eng. July 25, 1902

LOBO, GUSTAVE, Office Engineer, V. M. Braschi & Bro., 'Callé-Cadera No. 2 Mexico City, Mexico. June 28, 1901

LOCKE, FREDERICK M., Victor, N. Y. Apr. 23, 1903

LODYGUINE, ALEXANDER, St. Petersburg, Russia. Oct. 24, 1902

LOEWENTHAL, MAX, Consulting Electric Heating Engineer, 150 Nassau St., New York City. Mar. 23, 1898

LOGUIN, ALEXANDER J., Draftsman, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Apr. 26, 1907

LOHMAN, FRANK HENRY, Electrician, Calumet and Arizona Mining Co., Douglas, Ariz. Apr. 22, 1904

LOHMANN, Alfred Perkins, Manager, Engineering Department, the B. F. Goodrich Co., 37 Marshall Ave., Akron, O. Mar. 27, 1903

LOHMANN, RALPH W., Electrical Engineer, San Francisco, Cal., Nov. 23, 1898

LOMAS, HAROLD, 636 Equitable Bldg., Baltimore, Md. May 19, 1903

LONG, EBEN WILMER, Erecting Engineer, Crocker-Wheeler Co., Ampere; res., 27 N. 18th St., East Orange, N. J. July 26, 1907

LONGBOTHAM, FRANK, Student, Brooklyn Polytechnic Institute; res., 322 Carlton Ave., Brooklyn, N. Y. Mar. 29, 1907

LOOMIS, EVERETT ERASTUS, 416 Summit Ave., Schenectady, N. Y. June 21, 1907

LORD, CHARLES EDWARD, Manager, Allis-Chalmers Co., Cincinnati, O. Oct. 27, 1905

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LORIMER, GEO. WM., Secy. and Treas., The American Machine Telephone Co., Ltd., Piqua, Ohio. Aug. 5, 1896

LORING, FRANK CARLTON, Columbia University; res., Livingston Hall, 115th St., and Amsterdam Ave., New York City. Sept. 28, 1906

LOTSPEICH, WILEY WALTER, Constructing Engineer and Superintendent, Marion Light and Power Co., Marion, N. C. Jan. 25, 1907

LOUGHRIDGE, C. H., Draftsman, Bureau of Filtration; res., Heberton Ave., and Jackson St., Pittsburg, Pa. Sept. 28, 1906

LOUIS, OTTO T., O. T. Louis Co., 59 Fifth Ave.; res., 100½ W. 130th St., New York City. Feb. 23, 1898

LOUTEY, GEORGE SPANGLER, Electrician, Yards & Dock Department, U. S. Navy; res., 2418 N. 32d St., Philadelphia, Pa. Oct. 23, 1903

LOVEJOY, D. R., Electrical Engineer, U. S. E. M. Co., 303 W. 29th St., New York City. Apr. 28, 1897

LOVELESS, WAIT REYNOLDS, Construction Engineer, Illinois Steel Co., res., 148 79th St., Chicago, Ill. Oct. 28, 1904

LOVERRIDGE, IRVING, Western Electric Co., North Woolwich, London, Eng. Oct. 23, 1903

LOWE, ERNEST A., Electrical Engineer, The Lowe Electric Co., 54 Vesey St., New York City; res., Plainfield, N. J. June 19, 1903

LOWENBERG, LAURENT, Electrical Engineer, Reliance Engineering Co., 311 Fourth National Bank Bldg., Cincinnati, Ohio. Feb. 27, 1903

LOWENSTEIN, FRITZ, Consulting Engineer, 1555 Broadway; res., 102 E. 61st St., New York City. June 15, 1904

LOWNDES, ANDREW JACKSON, Engineer, Kinsman Block System Co., Wolcott, Kan. Mar. 1, 1907

LOWSON, DAVID, Electrical Inspector, N. Y. Board of Education, 59th St. and Park Ave., New York City. Feb. 28, 1902

LOWTHER, CHRISTOPHER MEYER, Riverside, Conn. Nov. 23, 1900

LUCAS, FRED L., Spring River Power Co., Joplin, Mo. Jan. 23, 1903

LUCAS, JAMES CLARENCE MERRYMAN, Electrical Contractor, 303 Courtland St., Baltimore, Md. May 20, 1902

LUDVIGSEN, HANS VALDEMAR, Electrochemical Engineer, 108 Oesterbrogade, Copenhagen, Denmark. Nov. 22, 1901

LUDWIG, RUDOLF EMMANUEL, Electrical Engineer, Ludwig & Co., 513 Empire Building, Atlanta, Ga. May 17, 1904

LUEPKE, FRANZ PAUL, Chief Elec. Engr.,South Jersey Gas, Electric & Traction Co.; res., 222 East State St., Trenton, N. J. Mar. 27, 1903

LUKES, GEORGE HOLT, General Superintendent, North Shore Electric Co., 1619 Orrington Ave., Evanston, Ill. Oct. 25, 1901

LUKES, JOSEPH BRIAN, Superintendent, Seattle Electric Co., Seattle, Wash. Mar. 25, 1904

LUNDELL, ROBERT, Electrical Engineer, 527 W. 34th St.; res., 9 W. 68th St., New York City. Feb. 7, 1890

LUNDIE, JOHN, Consulting Engineer, 52 Broadway, New York City. Nov. 22, 1899

LUNDQUIST, RUBEN ALVIN, In charge transmission line construction, La Crosse Water Power Co., La Crosse, Wis. Oct. 26, 1906

LUNN, ERNEST, Superintendent of Storage Batteries, Chicago, Edison Co., 139 Adams St., Chicago, Ill. Mar. 29, 1907

LUSK, WILLIAM CLARDY, Agent, General Electric Co., 83 Cannon St., London E. C., England. Sept. 26, 1902

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LYFORD, OLIVER S., JR., Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. Apr. 26, 1899

LYLE, THOMAS RANKEN, *M. A., Sc. D.*, Professor University of Melbourne, Toorak, Melbourne, Victoria. Apr. 27, 1906

LYMAN, CHESTER WOLCOTT, *M. A.*, Assistant to President International Paper Co., 30 Broad St., New York City. Sept. 19, 1894

LYNAH, JAMES, Purchasing Department, E. I. du Pont Co., Wilmington, Del. Oct. 27, 1905

LYNCH, DOSSEY MONTGOMERY, Electrical Inspector, Insurance Exchange of Memphis, 9 Madison St., Memphis, Tenn. Sept. 22, 1905

LYNCH, JOHN COOPER, Traffic Engineer, New York Telephone Co., 15 Dey St.; res., 122 East 18th St., New York City. May 20, 1902

LYNDON, LAMAR, Consulting Electrical Engineer, 80 William St.; res., 243 W. 98th St., New York City. Sept. 27, 1901

LYNN, WM. A., Electrician, 87 North Priest St., San Jose, Cal. Jan. 25, 1899

LYON, HENRY HOPKINS, Inspector, Cataract Power and Conduit Co., 718 Fidelity Bldg.; res., 190 Hodge Ave., Buffalo, N.Y. Oct. 27, 1905

LYON, WALDO VINTON, Assistant, Dept. of Electrical Engineering, Massachusetts Institute of Technology, Boston, Mass. Mar. 1, 1907

LYON, WILLIAM WARREN, JR., Student, Columbia University; res., 155 West 92d St., New York City. Jan. 27, 1907

LYONS, JOSEPH, Patent Solicitor, with Gustav Bissing, 908 G. St., Washington, D. C. June 24, 1898

LYSTER, THOMAS LEE BRENT, Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. Sept. 25, 1903

LYTCH, EDMOND SHAW, Electrician, Prairie Pebble Phosphate Co., Mulberry, Fla. Dec. 28, 1906

MABEN, GEORGE SALATHIEL, Engineer and Manager, City of Wellington, Electric Light and Power Co., Wellington, N. Z. Mar. 25, 1904

MACAFFEE, JOHN BLAIR, Chandler Bros. & Co., 3d and Walnut Sts., Philadelphia, Pa. Mar. 27, 1903

MACARTNEY, JOHN F., Managing Director, Macartney, McElroy & Co., Ltd., 53 Victoria St., London, Eng. May 16, 1899

MACCALLA, CLIFFORD SHERRON, Assistant to General Manager, The Washington Water Power Co., Spokane, Wash. June 28, 1901

MACDONALD, JAMES ARCHIBALD, Chief Draughtsman, Noyes Bros., Ann St., Roslyn, Dunedin, N. Z. Jan. 26, 1906

MACDONALD, JAMES ENON, Secretary, Joint Pole Committee, 444 Pacific Electric Building, Los Angeles, Cal. Jan. 23, 1903

MACDONALD, SAMUEL FREMONT, President, Ashtabula Hide and Leather Co., Ashtabula, Ohio. Mar. 23, 1906

MACDOUGALL, ALAN C., Assistant Superintendent, Pittsburg Reduction Co., Massena, N. Y. Apr. 28, 1905

MACDOWELL, ANDREW SEMPLE, District Engineer, Westinghouse Electric and Mfg. Co., University Bldg., Syracuse, N.Y. Mar. 1, 1907

MACFARLANE, WALTER LUTON, Superintendent M. P. Davis, Mille Roches, Ont. May 19, 1903

MACGAHAN, PAUL, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

MACGREGOR, WILLARD H., Westinghouse Electric & Mfg. Co., 11 Pine St.; res., Bayside, L. I. Jan. 20, 1897

MACHALSKE, FLORENTIN JOSEPH, Chemist, Brooklyn, N. Y. Sept. 25, 1903

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MACHEN, CHARLES HUDSON, President, Machen & May Electrical Mfg. Co.; 12th and Buttonwood Sts., Philadelphia, Pa. Jan. 23, 1903

MACK, WILLIAM G., Secretary and Treasurer, Cascade Milling Co., Sioux Falls, S. D. Apr. 27, 1906

MACKAY, JAMES LESLIE, Engineer, Westbury Electric Light & Power System, Sawyerville, Que. Apr. 23, 1903

MACKAY, WILLIAM, Student American Institute; res., 186 East 104th St., New York City. June 19, 1903

MACKEEN, RUPERT THOMAS Electrical Engineer, Wirt Mfg. Co. Burrage, Mass. Oct. 24, 1902

MACLAREN, MALCOLM, Electrical Engineer, Westinghouse Electric and Mfg. Co.; res., 5230 Westminster St., Pittsburg, Pa. July 28, 1905

MACNAUGHTAN, JAMES, 1133 Main St., Buffalo, N. Y. June 14, 1905

MACNUTT, BARRY, Assistant Professor, Physics, Lehigh University, South Bethlehem, Pa. June 21, 1907

MACOMBER, GEORGE STANLEY Asst. Prof. Electrical Engineering, Cornell University, Ithaca, N. Y. Aug. 22, 1902

MACOMBER, IRWIN JOHN, Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City; res., Richmond Hill, N. Y. Mar. 28, 1900

MACVAUGH, HERBERT WAYNE, District Manager, Cutter Electric and Mfg. Co., 1406 Machesney Building, Pittsburg, Pa. Feb. 23, 1906

MACY, OLIVER CROSBY, Manager, Cairo Electric & Traction Co., Cairo, Ill. July 19, 1904

MADDEN, JOHN FREDERICK SCARTH, Student, Toronto University; res., 7 Bedford Road, Toronto, Ont. Mar. 27 1903

MADDOCKS, WILLIAM SAMUEL, Erecting Engineer, Westinghouse E. & Mfg. Co., 730 Board of Trade Bldg., Boston, Mass. Apr. 26, 1907

MADGE, REGINALD GEORGE, Power Stations Superintendent, Mexico Light and Power Co., Mexico City, Mex. Jan. 25, 1907

MADSEN, JOHN PERCIVAL VISSING, Lecturer in Electrical Engineering, University of Adelaide, Adelaide, South Australia. May 19, 1903

MAETZEL, RICHARD, Engineering Department, New York Telephone Co., 15 Dey St., New York City. Sept. 28, 1906

MAGALHAES, GEORGE WILLIARD DE, Larkfield, N. Y. Mar. 24, 1905

MAGEE, LOUIS J., Electrical Engineer, 25 Broad St.; res., 14 E. 60th St., New York City. Apr. 2, 1889

MAGIE, LOUIS DE WITT, Works Engineer, Canadian General Electric Co.. Peterborough, Ont. Sept. 27, 1901

MAGNUS, BENJAMIN, Metallurgical Engineer, 19 West 94th St., New York City. Jan. 24, 1900

MAGRAW, LESTER ANDREW, Alternating Current Testing Crocker-Wheeler Co. Ampere, N. J. Jan. 25, 1907

MAHAFFEY, CLAYTON BENNET, Electrical Engineer, Curtis & Hine, Colorado Building, Colorado Springs, Colo. Jan. 23, 1903

MAHONEY, JOHN BERNARD, Superintendent, Hudson River Electric Power Co.; res., 126 John St., Utica, N. Y. Nov. 24, 1905

MAHONEY, JOSEPH MICHAEL, Inspector, City of Boston Wire Department; res., 21 Bailey St., Boston, Mass. June 21, 1907

MAHONEY, TIMOTHY S., Electrician, New York Fire Dept., 365 Jay St.; res., 162 Madison St., Brooklyn, N. Y. Aug. 25, 1905

MAHOOD, DAVID M., Chief Sub-inspector Equipment Department New York Navy Yard; res., 344 6th Ave., Brooklyn, N. Y. Mar. 1, 1907

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MAIBAUM, JEROME, Designer, New York Edison Co., res., 169 E. 80th St., New York City. Mar. 1, 1907

MAKI, HEIICHIRO, 488 Sankocho, Shirokane, Shiba, Tokyo, Japan. Aug. 5, 1896

MALCOLM, GEORGE HOAG, Electrical Engineering Department, Otis Elevator Co.; res., 78 Warburton Ave., Yonkers, N.Y. July 26, 1907

MALCOLM, NORMAN, Engineer, with George M. Painter, 423 Chamber of Commerce Building, Chicago, Ill. Apr. 28, 1905

MALCOLMSON, CHARLES TOUSLEY, Mechanical Engineer, Coal Testing Plant, World's Fair Grounds, St. Louis, Mo. May 19, 1903

MALLALIEU, WILBUR EMERSON, Asst. Electrical Inspector, Nat. Board of Fire Underwriters, 32 Nassau St., New York City. June 15, 1904

MALLETT, JOHN PURINTON, Chief Eng. and Designer, Northern Electric Mfg. Co.; res., 223 N. Carroll St., Madison, Wis. Feb. 27, 1903

MALOY, WILLIAM B., 700 N. Fulton Ave., Baltimore, Md. Apr. 28, 1905

MALTHA, GERARD SYBREN, Electrical Engineer, Plant Eng. Dept., Western Electric Co., Hawthorne, Ill. Apr. 27, 1906

MALTMAN, JOHN SCOTT, Superintendent, Kankakee Electric Light Co., Kankakee, Ill. June 21, 1907

MANGE, JOHN I., Engineer, Watertown Gas Light Co., Watertown, N. Y. Sept. 25, 1903

MANLEY, JOHN CHARLES, Assistant Construction Superintendent, Chicago Edison Co., 139 Adams St., Chicago, Ill. Apr. 26, 1907

MANLEY, ROBERT E., General Manager, Hanover Light Heat and Power Co., Hanover Pa. Mar. 29, 1907

MANLEY, RUSH EMMETT, Chief Inspector, Central Union Telephone Co., 1517 Worthington St., Columbus, O. Mar. 25, 1904

MANN, CHARLES ALLEN, Engineering Salesman, General Electric Co. Omaha, Neb. Nov. 24, 1905

MANN, WILLIAM LOWRY, Field Engineer, Shawinigan Water and Power Co., Montreal, P. Q. May 19, 1903

MANSFIELD, EDWARD STACEY, Edison Electric Illuminating Co., 70 State St., Boston, Mass. May 17, 1904

MANSFIELD, R. H. JR., Cutler-Hammer Mfg. Co., Milwaukee, Wis. Sept. 28, 1898

MANSON, ARTHUR JAMES, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Aug. 25, 1905

MANSON, DANIEL EDGAR, Manager, Westinghouse Electric and Mfg. Co., Boston; res., 67 Perry St., Brookline, Mass. Jan. 25, 1907

MANSON, RAY HERBERT, 1st Assistant Engineer, Dean Electric Co., Elyria, Ohio. Nov. 21, 1902

MANVEL, FREDERIC IRA, Testing Engineer, Stanley G. I. Electric Mfg. Co.; res., 631 North St., Pittsfield, Mass. Nov. 23, 1906

MANVILLE, CHARLES B., Electrical Engineer's Assistant Otis Elevator Co.; res., 1160 Nepperham Ave., Yonkers, N. Y. Aug. 22, 1902

MANYPENNY, JOSEPH POPE, Philadelphia Electric Construction Co., 914 Filbert St., Philadelphia, Pa. Mar. 27, 1903

MARBURG, LOUIS C., Electrical Engineer, Allis-Chalmers Co., Milwaukee, Wis. Feb. 28, 1902

MARKEL, HARLEY R., Electrical Inspector, Ohio Inspection Bureau, 902 Conover Building, Dayton, Ohio. June 21, 1907

MARKLE, HERBERT, Sales Engineer, Northern Electric Mfg. Co., 425 Monadnock Building, Chicago, Ill. Dec. 19, 1902

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MARLOW, WAYLAND CLINTON, Electrical Engineer, The Natural Food Co., Niagara Falls, N. Y. Jan. 23, 1903

MARRIOTT, ROBERT HENRY, Electrical Engineer, American Deforest Wireless Tel. Co., 566 High St., Denver, Colo. Sept. 28, 1906

MARSH, CHARLES MERCER, New York Transportation Co., 817 8th Ave., New York City. Feb. 27, 1903

MARSH, HARRY BOWMAN, Secretary, The Sanborn & Marsh Electric Co.; res., 1131 North Illinois St., Indianapolis, Ind. Mar. 28, 1900

MARSHALL, CLOYD, *E. E.*, Engineer, American De Forest Wireless Telegraph Co., 42 Broadway, New York City. Apr. 25, 1900

MARSHALL, NORMAN, President and Manager, Marshall-Sanders Co., 301 Congress St., Boston, Mass. Aug. 22, 1902

MARSHALL, ST. JULIEN RAVENEL, Electrical Engineer, Gwathmey-Mackall Eng'g. Co.,Atlantic Trust Bldg., Norfolk, Va. Nov. 24, 1905

MARSTON, ANSON, Dean of Division of Engineering, Iowa State College, Ames, Iowa. July 19, 1904

MARTIGNONE, DOMENICO, Constructing Engineer, General Electric Co., Schenectady, N. Y. June 14, 1905

MARTIN, FRANK, Engineer, American Hard Rubber Co., College Point, N. Y. Oct. 21, 1890

MARTIN, GEORGE W., Assistant to resident engineer, Ford, Bacon and Davis, Pine Bluff, Ark. Mar. 29, 1907

MARTIN, HERBERT, Prof. Eng., Oerlikon Works, Zurich, Switzerland. May 15, 1905

MARTIN, JAMES FRANK, Foreman in Testing Laboratory, Allegheny County Light Co., Pittsburg, Pa. Mar. 1, 1907

MARTIN, JOHN, Assistant Designing Engineer, British Thomson-Houston Co., Ltd.; res., Belgrave, Rugby, Eng. Apr. 26, 1907

MARTIN, JOHN, Agent, Stanley Electric Mfg. Co., Rialto Bldg., San Francisco, Cal. July 27. 1898

MARTIN, LEWIS GEORGE, Electrical Engineer, The Okonite Co., Ltd., 253 Broadway, New York City. Apr. 23, 1903

MARTIN, PERCY, Manager, The Daimler Motor Co., Coventry, Eng. Jan. 29, 1904

MARTIN, SIDNEY B., Consulting and Constructing Electrical Engineer, Pittsburg, Pa. Nov.21, 1902

MARTIN, T. COMMERFORD, [*Past-president*] Editor, *The Electrical World and Engineer*, 239 W. 39th St., New York City. Apr. 15, 1884

MARVIN, RICHARD HALE, Testing Department, General Electric Co., Schenectady, N. Y. July 19, 1904

MASJOAN, JUAN, *M. E. in E. E.* Parana, Argentine Republic. Dec. 15, 1905

MASON, EDWARD JARVIS KING, Westinghouse, Church, Kerr and Co., 10 Bridge St., New York City. Mar. 29, 1907

MASON, HOBART, *B. S.*, *E. E.*, Electrical Engineer, New York, New Jersey Teleph. Co., 15 Dey St., New York City. June 28, 1901

MASON, ROGER, Electrical Engineer, Bond Electric Co., San Francisco, Cal. June 14, 1905

MASON, WALTER LLOYD, Salesman, Westinghouse Electric and Mfg. Co., Land Title Bldg., Philadelphia, Pa. Mar. 29, 1907

MASSON, RAYMOND S., Consulting Electrical Engineer, 824 Westlake Ave., Los Angeles, Cal. Apr. 26, 1899

MASTERS, ARTHUR HENRY, Representative of Westinghouse, Church, Kerr & Co.; res., 660 Maryland Ave., Pittsburg, Pa. Jan. 23, 1903

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MASTERS, WILFORD THOMPSON, Superintendent, of Power Distribution B. E. Ry. Co., 439 Albany St., Boston, Mass. Apr. 26, 1907

MATEER, JESSE EUGENE, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. July 19, 1904

MATEER, ROSS BOOK, Electrical Engineer, Combustion Utilities Co., 60 Wall St., New York City. Jan. 23, 1903

MATHER, EUGENE HOLMES, Manager, Cumberland Ill. Co.; Treasurer, Portland Lighting and Power Co., Portland, Me. Apr. 28, 1897

MATHER, LEWIS ROOT, Electrical Contractor, 113 Miller St., Utica, N. Y. Jan. 26, 1906

MATHER, ROBERT FENTON, Assistant Superintendent, Winnipeg Electric Street Railway Co., Lac du Bonnet, Manitoba. June 21, 1907

MATHEY, EWARD DU BOIS, Chief Draughtsman, Elec. Dept., Westinghouse, Church, Kerr & Co., New York City. Jan. 25, 1907

MATHIS, LOUIS J., Engineer, General Electric Co., 44 Broad St., New York City. Apr. 28, 1905

MATTHEWS, HUBERT WILLARD, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Great Falls, S. C. June 21, 1907

MATTHIAS, J. INGLES, Manager, Licking Light and Power Co., Newark, Ohio. Mar. 24, 1905

MAUGER, SAMUEL WARREN, Assistant Engineer, Switchboard Department, General Electric Co., Schenectady, N. Y. Sept. 28, 1906

MAUTNER, CHARLES, Electrical Engineer, 5 East 13th St., New York City. Feb. 26, 1904

MAXIM, HIRAM PERCY, Electric Vehicle Co., Hartford, Conn. Jan. 3, 1902

MAXWELL, ALEXANDER, Assistant Superintendent 3d District, New York Edison Co.; res., 45 West 26th St., New York City. Nov. 20, 1903

MAXWELL, EUGENE, Phœnix Construction Co., Raleigh, N. C. Aug. 5, 1896

MAXWELL, HOWARD, Designing Engineer, General Electric Co.; res., 832 Union St., Schenectady, N. Y. Apr. 23, 1903

MAXWELL, MARSHALL ANDREWS, Consulting Electrical Engineer, 82 Beaver St., New York City. Apr. 28, 1905

MAYER, FRANKLIN JULES, District Manager, Wisconsin Telephone Co., 16 S. Carroll St., Madison, Wis. Feb. 23, 1906

MAZZOLANI, GIULIO, Electrical Engineer Societa delle Tramvie e ferrovie Electriche di Roma Via Firenze, 47, Rome, Italy. Mar. 29, 1907

MCALLISTER, ADAMS STRATTON, Editorial Department, Electrical World & Engineer, 239 W. 39th St., New York City. Mar. 28, 1902

MCANGE, WILLIAM NORMAN, JR., Manager, Atlantic Coast Construction Co., Suffolk, Va. Aug. 17, 1904

MCCABE, EDWARD HENRY, JR., Switchboard Operator, Interborough Rapid Transit Co., New York City. May 15, 1905

MCCALL, JOSEPH B., President, The Philadelphia Electric Co., N. E. cor. 10th and Sansom Sts., Philadelphia, Pa. Apr. 22, 1904

MCCANDLESS, WILSON, Treasurer, United Electric Construction Co., 1714 Sansom St., Philadelphia, Pa. Dec. 28, 1906

MCCARTER, ROBERT D., JR., Electrical Engineer, Bath Electric Tramway, Ltd., Walcot St., Bath, Eng. May 16, 1899

MCCARTHY, E. D., McCarthy Bros. & Ford, 41 E. Eagle St.; res., 540 Norwood Ave., Buffalo, N. Y. Nov. 18, 1896

MCCARTHY-JONES, CHRISTOPHER HOWEL, Engineer on Staff, British Thomson-Houston Co., Rugby, England. Mar. 29, 1907

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McCarty, Francis Alexander, 31 Queen St., Melbourne, Vic. June 28, 1901

McCaskey, William Tyndale, Electrical Installation Co., Monadnock Bldg., Chicago, Ill. Sept. 25, 1903

McCaskill, Kenneth, Engineering Dept., N. Y. C. R. R. Room 1235, 335 Madison Ave., New York City. Feb. 26, 1904

McClain, Frank Laval, 3644 Botanical Ave., St. Louis, Mo. June 19, 1903

McCleary, Ernest, Electrical Contractor, McCleary-Harmon Co., 411 Stevens Building, Detroit, Mich. Apr. 23, 1903

McClellan, Ross St. John, Engineer, Electric Bond & Share Co., 62 Cedar St., New York City. Oct. 28, 1904

McClellan, William, *Ph. D.*, Engineer, Allison Campion, McClellan Co., 90 West St., New York City. Feb. 26, 1904

McClelland, William, Electrical Engineer, Admiralty, London, S. W. Eng. May 19, 1903

McClenathen, Robert, Engineer, International Harvester Co., Auburn N. Y. May 16, 1899

McClintic, Emmett W., American Gas & Electric Co., Witherspoon Building, Philadelphia, Pa. May 14, 1906

McClintock, William Mckean, Electrical Engineer, McClintock Manufacturing Co., 772 Hague Ave., St. Paul, Minn. June 21, 1907

McClure, William J., Electrical Engineer & Contractor, 160 Fifth Ave.; res., 358 W. 55th St., New York City. Apr. 25, 1900

McClurg, W. A., Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. Dec. 20, 1893

McConahey, William M., Electrical Engineer, Westinghouse E. & M. Co.; res., 5723 Rippey St., Pittsburg, Pa. Sept. 27, 1901

McCormick, Bradley Thomas, Allis-Chalmers-Bullock, Montreal, Que. Jan. 29, 1904

McCoy, Carl, Draftsman, Washington Water Power Co., 716 1st Ave., Spokane, Wash. Oct. 26, 1906

McCoy, John Angus, Supt. of Construction, The New England Teleph. & Tel. Co.; res., 62 Main St., Somerville, Mass. Apr. 23, 1903

McCoy, Walter Ehmsen, Electrical Engineer, United Electric Light and Power Co., 1170 Broadway, New York City. May 19, 1903

McCulloh, James S., Superintendent of Buildings, New York Telephone Co., 15 Dey St.; res., 267 W. 71st St., New York City. Mar. 25, 1904

McCullough, Homer, Electrician, Pittsburg & Montana Copper Co., Butte, Mont. Dec. 23, 1904

McCurdy, George Alexander, Electrical Engineer, Madison Sq. Theatre; res., 8 W. 66th St., New York City. Apr. 26, 1907

McDermott, Franklin Pierce, Jr., Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 1, 1907

McDonald, Walter D., Salesman, Westinghouse E. & M. Co., 171 La Salle St., Chicago, Ill Sept. 25, 1903

McDonnell, Isham Fennell, Manager, Southern States Electric Co., Birmingham, Ala. June 14, 1905

McDougall, George Kinghorn, Indiana & Louisville Traction Co., 308 Columbia Building, Louisville, Ky. Aug. 25, 1905

McDuffee, Edgar Jerome, Assistant Engineer, General Electric Co., 84 State St., Boston, Mass. Apr. 23, 1903

McElroy, James F., Consulting Engineer, Consolidated Car Heating Co., 131 Lake Ave., Albany, N. Y. Nov. 15, 1892

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McFedries, Sherman Miller, Secretary and Treasurer, J. L. Schureman Co., 80 W. Jackson Blvd., Chicago, Ill. June 21, 1907

McFeeley, John, Assistant, Public Service Corporation of New Jersey-418 Federal St.; res., 615 Line St., Camden, N. J. Feb. 26, 1904

McGeorge, Harold, Vice-President and General Manager, McGeorge Mfg. Co., Cleveland, O. Oct. 28, 1904

McGillivray, John Edgar, Telephone Engineer and Constructor, 125 Boren Ave., North, Seattle, Wash. Sept. 28, 1906

McGrath, William Henry, Electrical Engineer, Houghton Co., Elec Co., Houghton, Mich. Mar. 28, 1902

McGraw, Frank H., Superintendent Construction, Westinghouse, Church, Kerr and Co., 8 Bridge St., New York City. Mar. 24, 1905

McGraw, James H., President, McGraw Publishing Co., 239 W. 39th St., New York City; res., Madison, N. J. Sept. 27, 1901

McGregor, Alexander Grant, Electrical Engineer, Anaconda Copper Mining Co., Anaconda, Mont. Sept. 28, 1906

McIntyre, Henry Knox, Assistant, Engineering Department, New York Telephone Co., 15 Dey St., New York City. Sept. 26, 1902

McJunkin, Paul, Consulting Engineer, Fahn & McJunkin, 201 E. 16th St., New York City. May 15, 1905

McKay, Marshall Cameron, Supt. American River Electric Co., 320 E. Webber Ave., Stockton, Cal. May 19, 1903

McKay, Maurice Parker, Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St.; res., 211 W. 69th St., New York City. May 17, 1904

McKay, Robert, Barrister and Solicitor, McKay, Dods & Grant, King St., Toronto, Ont. Jan. 29, 1904

McKee, Frank E., Electrical Engineer, Pressed Steel Car Co., McKees Rocks, Pa. Oct. 27, 1905

McKee, William Norris, Consulting Electrical Engineer, 509 Wait Building, Decatur, Ill. July 19, 1904

McKelway, George Hubbell, Assistant Electrical Engineer, Brooklyn Heights R. R., Brooklyn, N. Y. Dec. 18, 1903

McKenzie, Roderick R., Station Engineer, San Juan Light and Transit Co., San Juan, P. R. Apr. 27, 1906

McKindley, James Lampert, Engineering Department, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. June 19, 1903

McKinney, Robert F., Switchboard Operator, General Electric Co.; res., 932 Albany St., Schenectady, N. Y. Sept. 28, 1906

McKinstry, Archibald, Chief Assistant, Plant Department, British Westinghouse Electric and Mfg. Co., Manchester, Eng. Jan. 25, 1907

McKittrick, Frederick James Alexander, Managing Director, Australian Gen. Elec. Co., Melbourne, Australia. Sept. 22, 1905

McLaren, John Harold, Assistant Chief Engineer, Cincinnati, Newport and Covington Light and Traction Co., Newport, Ky. Mar. 29, 1907

McLaren, William Frederick, Draftsman, Ravenscliffe Ave., Hamilton, Ont. June 19, 1903

McLeary, Samuel Harvey, Electrical Engineer, Big Four Ice & Coal Co., Waco, Texas. Nov. 20, 1903

McLellan, William, Partner, Merz & McLellan, Collingwood Buildings, Newcastle-on-Tyne, Eng. May 19, 1903

McLimont, A. W., Engineer, Federal Electric Co., 141 Broadway, New York City. July 26, 1900

McMaster, James Clayton, Member of firm, McMaster Electric Construction Co., 114 North 3d St., Columbus, O. Apr. 22, 1904

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McMorrow, Charles P., Panama R. R. Co., La Boca Canal Zone, Pan. Jan. 25, 1907

McMurtry, Alden Lothrop, Superintendent, New York Motor Car Co., 141 W. 38th St.; res., 812 5th Ave., New York City. Aug. 25, 1905

McNaier, Joseph Treanor, Sales Manager, International Electric & Engineering Co., 150 Nassau St., New York City. Dec. 18, 1903

McNamee, Thomas Wilson, Superintendent, Wabash Electric Light Co., Wabash, Ind. Apr. 22, 1904

McNary, Charles Herbert, General Manager, Lewiston-Clarkston Co., Clarkston, Wash. Apr. 25, 1902

McNeill, Jacob Rufus, Electrical Engineer, Proctor and Gamble Co., Ivorydale; res., 831 Williams Ave., Hartwell, O. Apr. 27, 1906

McNicol, Donald, Electrician, Postal Telegraph Co., Salt Lake City, Utah. Nov. 24, 1905

McNitt, Robert Joseph, Superintendent, Acker Process Co.; res., 124 Third St., Niagara Falls, N. Y. Sept. 28, 1906

McNulty, Peter Cutting, Jr., Borough Engineer, Edgewood Park, Pa. Oct. 28, 1904

McPherson, Norman Crawford, Engineering Staff, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. Sept. 25, 1903

McQuarrie, J. L., Assistant Chief Engineer, Western Electric Co., 259 So. Clinton St., Chicago, Ill. Apr. 26, 1907

Mcquiston, Jackson Clendenon, Manager, Westinghouse Cos' Publishing Dept., Pittsburg, Pa. Mar. 1, 1907

McRae, Frank George, Electrical Inspector, Hudson River Electric Power Co., 192 3d St., Albany, N. Y. Mar. 29, 1907

McRae, John, Master Signal Electrician, Signal Corps, U. S. 263 Summer St., Boston, Mass. Jan. 27, 1905

McTaggart, William A., General Electric Co.; res., 427 Smith St., Schenectady, N. Y. Mar. 25, 1904

Mead, George Alvin, Chief Engineer, The Ohio Brass Co., Mansfield, Ohio. Sept. 25, 1903

Mead, William Algernon, Foreman, Harry Alexander Co., 18 W. 34th St.; res., 405 W. 17th St., New York City. Jan. 25, 1907

Meade, Ralph Cutler, Foreman of Sub-station, Interborough Rapid Transit Co., New York City. Apr. 27, 1906

Meadows, George William, Wireman, Jamestown Exposition Co; Pine Beach, Va. June 21, 1907

Meadows, Harold Gregory, Meadows, Williams & Co., 214 Fidelity Bldg., Buffalo, N. Y. Sept. 23, 1896

Medbery, S. C., Jr., Engineering Department, N. Y. & N. J. Telephone Co., 15 Dey St., New York City. Oct. 24, 1902

Meeker, Lewis Edgar, Wire Chief, N. Y. & N. J. Telephone Co.; res., 44 Linden St., Brooklyn, N. Y. Nov. 24, 1905

Mees, Carl Leo, President and Professor of Physics, The Rose Polytechnic Institute, Terra Haute, Ind. May 19, 1903

Mees, Curtis Adolph, Charge of Design, Southern Power Co., Charlotte, N. C. Mar. 1, 1907

Meister, James Franklin, Stone & Webster Engineering Corporation, 84 State St., Boston, Mass. Aug. 25, 1905

Mendenhall, Bayard William, Manager, Ely Light & Power Co., Ely, Nevada. Sept. 28, 1906

Mentz, Henry Alvan, Consulting Electrical Engineer, 714 Hennen Building, New Orleans, La. Dec. 28, 1906

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MERENESS, GERIT NEWTON, Engineering Dept., C. D. & P. Tel., Co., Pittsburg, Pa. Jan. 29, 1904

MERIWETHER, RICHARD, Superintendent, Louisville and Eastern Railroad, 511 West Green St., Louisville, Ky. June 21, 1907

MERKLE, WILLIAM S., Vice-president Ewing Merkle Electric Co.; res., 2601 Louisiana Ave., St. Louis, Mo. Apr. 23, 1903

MERRIAM, EZRA BASSETT, Electrical Engineer, General Electric Co., Schenectady, N. Y. Jan. 26, 1906

MERRICK, ELDRIDGE GERRY, Stanley G. I. Electric Mfg. Co., res., 27 Pomeroy Ave., Pittsfield, Mass. Mar. 24, 1905

MERRICK, FRANK ANDERSON, Manager of Works, Canadian Westinghouse Co. Ltd., Hamilton, Ont. Mar. 29, 1907

MERRILL, BARRETT MORRIS, Electrical Engineer, Washington Power Co., 1618 Mallon Ave., Spokane, Wash. Apr. 23, 1903

MERRILL, CHARLES PALMER, Cable Dept., Dean Electric Co., Elyria, Ohio. Apr. 28, 1905

MERRILL, E. A., Manager, New York Office, McIntosh, Seymour & Co., 26 Cortlandt St., New York City. Sept. 20, 1893

MERRILL, EDWARD BELDEN, Power Construction Department, Carnegie Library, Winnepeg, Manitoba. May 15, 1905

MERRILL, JOSEPH F., Professor of Physics and Electrical Engineering, University of Utah, Salt Lake City, Utah. May 21, 1901

MERRILL, JOSIAH L., Electrical Engineer, Burke Electric Co., 1526 Park Building, Pittsburg, Pa. Sept. 25, 1895

MERRILL, MELDON HUMPHREY, Sales Engineer, Westinghouse Electric and Mfg. Co., 716 Board of Trade Building, Boston, Mass. Apr. 22, 1904

MERRITT, BENJAMIN F., Superintendent, Electric Goods, Mfg. Co., Canton, Mass. Mar. 27, 1903

MERZ, CHARLES H., 28 Victoria St., Westminster, London S. W., Eng. Sept. 25, 1895

MESCHENMOSER, WILLIAM F., Engineer, Kinsman Block System Co., 55 Dey St., New York City. Sept. 28, 1906

MESSICK, CHARLES, Electrical Engineer, Room 92, Cotton Exchange Bldg., New York City. Dec. 18, 1903

MESTON, CHARLES ROBERT, Vice-president and Superintendent, The Emerson Mfg. Co., 5619 Cates Ave., St. Louis, Mo. May 19, 1903

METTLER, HANS WILLI., Draughtsman, Ontario Power Co., Niagara Falls, N. Y. Apr. 22, 1904

MEYER, ALBERT P., Engineer, Rowland Telegraphic Co., 107 E. Lombard St., Baltimore, Md. Feb. 24, 1905

MEYER, EDWARD B., Engineering Assistant, Public Service Corporation of N. J.; res., 789 Clinton Ave., Newark, N. J. June 14, 1905

MEYER, EINAR HONORATUS, Ontario Power Co., Niagara Falls, N. Y. May 14, 1906

MEYER, EUGENE DANIEL, Consulting Engineer, Falkenau Electrical Construction Co., Paw Paw, Mich. Mar. 29, 1907

MEYER, HANS JULIUS, Westinghouse Electric & Mfg. Co., 1110 Hibernia Bank Bldg., New Orleans, La. Nov. 25, 1904

MEYER, HANS S., Electrical Engineer, Norddeutsche Machinen und Armaturen-Fabrik, Bremen, Ger. July 27, 1889

MEYER, HENRY CODDINGTON, JR., Consulting Mechanical Engineer, 1 Madison Ave., New York City; res., Montclair, N.J. Apr. 28, 1905

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MEYER, HERMANN HENRY BERNARD, Expert Cataloguer, Library of Congress, Washington, D. C. Feb. 24, 1905

MEYER, JULIUS, Consulting Engineer, 60 Liberty St., New York City. Oct. 25, 1892

MEYERS, ALVIN, Engineering Department, The Telluride Power Co., Provo, Utah. Aug. 22, 1902

MEYGRET, ACHILLE, Consulting Engineer, Room 1209, 110 West 34th St., New York City. July 19, 1904

MICHOD, CHARLES LOUIS, Salesman Westinghouse Electric & Mfg. Co., Brown-Marx Building, Birmingham, Ala. July 28, 1903

MIDDLETON, A. CENTER, General Electric Co., 44 Broad St., New York City. May 16, 1899

MIEHLING, RUDOLPH, Engineer, 29 Hamilton Terrace, New York City, Sept. 25, 1903

MILCH, MAURICE, Engineer, Nagy-Bittse, Hungary. Apr. 22, 1904

MILES, FREDERICK, Superintendent of Power, New Milford Power Co., Gaylordsville, Conn. Mar. 1, 1907

MILES, J. WALTER, Electrical Engineer, Westinghouse Electric and Mfg. Co., Irwin, Pa. Apr. 25, 1903

MILFORD, GEORGE ROSCOE, Superintendent of Power House, Northern California Power Co., Redding, Cal. Oct. 28, 1904

MILLAR, LESLIE WALKER, Inspector, Edison Electric Illuminating Co., 516 Atlantic Ave., Boston, Mass. Dec. 28, 1906

MILLAR, PRESTON S., Asst. to Mgr. Electrical Testing Laboratories, 80th St. and East End Ave., New York City. Jan. 23, 1903

MILLER, ALPHONSUS JOSEPH, Laboratory Assistant, Western Electric Co., 463 West St., New York City. Mar. 28, 1902

MILLER, ALVIN AUGUSTUS, Salesman, Westinghouse Electric and Mfg. Co., 314 Occidental Ave., Seattle, Wash. Apr. 23, 1903

MILLER, ANDREW OTTERSON, Correspondent, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City. Mar. 1, 1907

MILLER, ANGUS KENNETH, Assistant Engineer, Brooklyn Rapid Transit Co.; res., 85 Clinton St., Brooklyn, N. Y. Apr. 26, 1907

MILLER, ARLIN D., Truckee River, General Electric Co., Reno, Nev. Nov. 23, 1906

MILLER, DECATUR STERIGERE, Electrical Engineer, Consolidated Railway Co.; res., 314 Crown St., New Haven, Conn. Apr. 27, 1906

MILLER, DWIGHT DANA, Salesman, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City. Apr. 25, 1902

MILLER, ELAM, Engineer, Pacific States Tel. and Tel. Co., Oakland, Cal. May 15, 1905

MILLER, FRANK HEGAN, Superintendent Louisville Railway Co.; res., 521 W. Hill, Louisville, Ky. Mar. 25, 1904

MILLER, GEORGE E., Westinghouse E. & M. Co., New England Building, Cleveland, Ohio. Feb. 28, 1902

MILLER, HERBERT S., Electrical Engineer, Diehl Mfg. Co., res., 1025 E. Jersey St., Elizabeth, N. J. Mar. 22, 1899

MILLER, JAMES EDGAR, Commercial Engineer, Westinghouse Electric and Mfg. Co.; res., 316 East End Ave., Pittsburg, Pa. Sept. 28, 1906

MILLER, KEMPSTER B., Consulting Engineer, McMeen & Miller, 1454 Monadnock Block, Chicago, Ill. Sept. 28, 1898

MILLER, WALTER H., Manager Record Dept. (Phonograph) with Thomas A. Edison; res., 28 Mt. Vernon St., Orange, N. J. Sept. 27, 1901

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MILLER, WILFRED AMRAM, Designer, Hadaway Electric Heating & Engineering Co., 228 West Broadway, New York City. July 26, 1907

MILLER, WILLIAM NORTON, Assistant Electrical Engineer, Detroit River Tunnel Co., Detroit, Mich. June 21, 1907

MILLER, WILLIAM WALKER, Electrical Draftsman, U. S. Naval Constructors Office, Newport News, Va. Jan. 26, 1906

MILLS, CLARENCE VALENTINE, Manager and Superintendent, Lowell & Fitchburg St. Railway Co., Ayer, Mass. Nov. 24, 1905

MILMOW, ALBERT, Electrical Engineer, General Electric Co., 203 Trust Building, Charlotte, N. C. Oct. 28, 1904

MILNE, GEORGE G., Manager, Electrical Dept., Gould Storage Co., 341 Fifth Ave., New York City. Jan. 29, 1904

MINAMI, HAJIME, 2 Chome Kitahama, Osaka, Japan. Mar. 29, 1907

MINEHARDT, ERNEST HENERY, Operator, New Milford, Power Co., Gaylordsville, Conn. June 21, 1907

MINOR, JOHN W., JR., Secretary, Texas Fire Prevention Asso., 822 Wilson Building, Dallas, Tex. Mar. 27, 1903

MISAKI, SEIZO, Chief Engineer and Superintendent, Hanshin Elec. Railway Co., Nishiumeda-cho, Osaka, Japan. Dec. 27, 1899

MITCHELL, CHARLES HAMILTON, Consulting Engineer, 1004 Traders Bank Building, Toronto, Ont. Jan. 26, 1906

MITCHELL, GUY K., Superintendent, Crook-Horner Co., 301 N. Howard St., Baltimore, Md. Dec. 28, 1906

MITCHELL, PAUL E., General Superintendent Knoxville Railway & Light Co., Knoxville, Tenn. Sept. 28, 1906

MITCHELL, ROBERT, Electrician, North Shore Railroad Co., Sausalito, Cal. Nov. 24, 1905

MITCHELL, ROBERT HUGH, Student, Polytechnic Institute; res., 8612 Bay, 15th St., Brooklyn, N. Y. Nov. 23, 1906

MITCHELL, WILLIAM EDWARD, Electrical Engineer, Bahia Tramway Lt. & Power Co., Bahia, Brazil. Sept. 28, 1906

MITCHELL, SIDNEY Z., Vice-president, Electric Bond & Share Co., 62 Cedar St., New York City. Nov. 12, 1889

MIXER, CHARLES ADAM, Civil and Hydraulic Engineer, Rumford Falls Power Co., Rumford Falls, Me. Sept. 25, 1903

MONASCH, BERTHOLD, Electrical Engineer, Allgemeine Elektristats-Gesellschaft, N. 4, Schroederstrasse 6, Berlin, Ger. Dec. 15, 1905

MONEYPENNY, NELSON NORTH, Manager, Special Work Department, Alberene Stone Co., 223 E. 23d St., New York City. Mar. 27, 1903

MONJO, DOMINGO L., Westinghouse Electric & Mfg. Co., 424 Randolph Bldg., Memphis, Tenn. Dec. 23, 1904

MONRATH, GUSTAVE, Consulting Engineer, 7 E. 42d St., New York City. Apr. 26, 1901

MONTAGU, RALPH LECHMERE, Consulting Engineer, Oroville, Butte Co., Cal. Feb. 26, 1896

MONTELIUS, CARL, Assistant Engineer, Swedish State Railways, Ostermalmsg 48, Stockholm, Sweden. Feb. 23, 1906

MONTGOMERY, DUDLEY, Vice-president, Madison and Interurban Traction Co., Madison, Wis. Sept. 28, 1906

MONTIGNANI, JOHN OLIVER, Assistant Engineer, Rochester Railway Co.; res., 26 Phelps Ave., Rochester, N. Y. Mar. 23, 1906

MOODY, VIRGINIUS, DANIEL, F. S. Pearson, 25 Broad St., New York City. Dec. 27, 1899

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MOODY, WALTER SHERMAN, Designing Engineer, General Electric Co.; res., 3 Avon Road, Schenectady, N. Y. Nov. 23, 1906

MOORE, CLIFFORD, THOMPSON, Electrician, U. S. Navy Yard, League Island, Pa. May 17, 1904

MOORE, GEORGE HOLMES, Electrical Engineer, Kilbourne and Clark Co., 816 Terry Ave., Seattle, Wash. Jan. 25, 1907

MOORE, HAROLD THOMPSON, Mechanical Engineer, Dodge & Day; res., 4535 Pulaski Ave., Germantown, Philadelphia, Pa. July 19, 1904

MOORE, HENRY ALEXANDER, Engineer, The Canadian Bullock Electric Mfg. Co., 200 McKinnon Bldg., Toronto, Ont. June 19, 1903

MOORE, HENRY DUBOIS BAILEY, Engineer, Western Electric Co.; res., 1 West 72nd St., New York City. June 21, 1907

MOORE, JOHN H., Electrical Equipment Station 4, Columbus Edison Co., res., 311 Arondale Ave., Columbus, O. Feb. 26, 1904

MOORE, JOHN PEABODY, Engineer, Keystone Construction Co., 509 Traction Bldg., Indianapolis, Ind. Apr. 25, 1900

MOORE, PERCIVAL, Vice-president and General Manager, Louisville & Eastern R. R., Anchorage, Ky. Mar. 27, 1903

MOORE, STANLEY H., Director of Manual Training, McKinley High School, St. Louis, Mo. Jan. 29, 1904

MOORE, WALLACE D., Mascot Oil Company, Maricopa, Cal. Nov. 25, 1904

MOORE, WILLIAM J., Wiring Department, Consolidated Gas and Electric Co., Youngstown, Ohio. Mar. 1, 1907

MOORE, WILLIAM WASHINGTON, Manager Engineering Department, 905 Title Guarantee Building, Birmingham, Ala. Jan. 25, 1907

MORA, MARIAN LOUIS, General Electric Co., 44 Broad St., New York City. Mar. 20, 1895

MORAN, WILLIAM M., Electrical Engineer, Chicago & Southern Traction Co., Chicago, Ill July 28, 1903

MORAWECK, ALVIN H., American Telephone & Telegraph Co., Boston, Mass. Apr. 23, 1903

MORDEY, WM. MORRIS, Consulting Electrician, 82 Victoria St., Grosvenor Mansions, Westminster, London, Eng. Sept. 22, 1891

MORDOCK, CHARLES T., Superintendent, Lighting and Power Department, Terra Haute Electric Co., Terra Haute, Ind. Sept. 25, 1903

MORECROFT, JOHN HAROLD, Instructor, Syracuse University; res., 473 Allen St., Syracuse, N. Y. Mar. 23, 1906

MOREHEAD, J. M., Engineer, Union Carbide Co., 157 Michigan Ave., Chicago, Ill. Mar. 28, 1900

MOREHEAD, ROY ARCHIBALD, Engineer, Pacific Telephone and Telegraph Co.; res., 622 S. Hill St., Los Angeles, Cal. Mar. 29, 1907

MOREHOUSE, H. H., Morehouse & Morrill, Chihauhau, Mex. Feb. 21, 1894

MORGAN, CARL LEON, With Simplex Electric Co., 110 State St.; res., 25 St. Cecilia St., Boston, Mass. Jan. 24, 1902

MORGAN, GODFREY, Moody & Brisbane Bldg., 7 Grand Court, Buffalo, N. Y. Oct. 25, 1901

MORGAN, JOSEPH, Consulting Engineer, Cambria Steel Co., Westmont, Johnstown, Pa. Apr. 26, 1907

MORGAN, THEODORE BLACKWELL, Transit Development Co., Kent Ave. and Rush St., Brooklyn, N. Y. Mar. 25, 1904

MORGAN, THOMAS BERNARD, Electrical Engineer, Metropolitan Railway; res., 6 Greenhill Crescent, Harrow, London, Eng. Nov. 24, 1905

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MORGAN, WILLIAM DUNCAN NICOLL, Chief Eng., Scottish Central Elec. Power Co., 34 North Bridge St., Edinburgh, Scotland. Dec. 28, 1906

MORGANS, FRANK DAVIS, Member of firm, H. L. Roper and Co.; res., 501 Wyoming St., El Paso, Tex. Apr. 26, 1907

MORGENSTERN, OTTO LESTER, Student, Brooklyn Polytechnic Institute; res., 77 Sumner Ave., Brooklyn, N. Y. June 21, 1907

MORITA, KADZUO, Engineer, 15 Kitaigacho Yotsua, Tokyo, Japan. Dec. 18, 1903

MORITZ, CHARLES HOLLAND, Construction Engineer, Aluminum Co. of America, Niagara Falls, N. Y. Dec. 19, 1902

MORLE, Richard Gilbert, Engineering Dept., New York Telephone Co., 15 Dey St., New York City. Apr. 28, 1905

MORLEY, EDGAR L., Supt. Hatzel & Buehler, 571 Fifth Ave., New York City. Sept. 25, 1895

MORRELL, HARRY B., Foreman Meter Department, New York, Queens Light and Power Co., Jamaica, L. I., N. Y. June 21, 1907

MORRILL, EDWARD FRANCIS, Central Union Telephone Co., Springfield, Ill. Feb. 28, 1902

MORRILL, THOMAS LEONARD, Electrical Engineer, Compania de Potencia Electrica de Colima, Colima, Mex. Aug. 17, 1904

MORRILL, WILLIAM CHARLES, Manager, Chas. Morrill, 277 Broadway; res., 24 W. 83d St., New York City. Jan. 23, 1903

MORRIS, A. SAUNDERS, Engineer, 1501 So. Front St., Philadelphia, Pa. June 15, 1904

MORRIS, DAVID KING, Lecturer, The University, Birmingham, Eng. Nov. 25, 1904

MORRIS, HARVEY, L., Salesman, Northern Electric Mfg. Co., Madison, Wis. Jan. 23, 1903

MORRIS, JOHN WILLIAM, Electrical Superintendent, The Reid Newfoundland Co., St. Johns, Newfoundland. Aug. 22, 1902

MORRIS, THOMAS ARTHUR, Electrical Engineer, Wonderland Co.; res., 239 W. 44th St., New York City. June 14, 1905

MORRISON, ARCHIBALD, BOSTWICK, JR., Salesman, S. M. Jones Co., 224 12th St., Toledo, O. Nov. 24, 1905

MORRISON, J. FRANK, Consulting Engineer, 317 N. Paca St., Baltimore, Md. Apr. 15, 1884

MORROW, BRYCE EUGENE, Manager Operating Dept., Hudson River Water Power Co., Glens Falls, N. Y. Mar. 25, 1904

MORSE, ARTHUR CURTIS, Technical Salesman, Western Electric Co., 463 West St., New York City. Mar. 1, 1907

MORSE, ERNEST CADWELL, Sales Engineer, Westinghouse Electric and Mfg. Co., Boston: res., 11 Dix St., Worcester, Mass. Mar. 1, 1907

MORSE, LEOPOLD GEORGE ESMOND, 14 Airlie Gardens, W. London, Eng. Nov. 25, 1904

MORSE, PERSE ABRAM, Manager Apparatus Department, Western Electric Co., 810 Spruce St., St. Louis, Mo. Mar. 23, 1906

MORTIMER, JAMES D., Engineer, Electric Bond and Share Co., 62 Cedar St., New York City. Mar. 28, 1900

MORTON, ALEX AMERTON, Ft. Wayne Electric Works, 623 Marquette Building, Chicago, Ill. June 15, 1904

MOSES, PERCY LAWRENCE, Assistant Engineer, Stone and Webster Engineering Corporation, 147 Milk St., Boston, Mass. Apr. 26, 1907

MOSES, RUFUS PAGE, Electrician, 526 National Ave., San Diego, Cal. Nov. 25, 1904

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MOSMAN, CHARLES TYLER, Electrical Engineer, General Electric Co., 84 State St., Boston, Mass. May 19, 1903

MOSS, CHARLES MACLEAN, Electrical Engineer, Westinghouse Electric & Mfg. Co.; res., 7728 Kelly St., Pittsburg, Pa. Dec. 15, 1905

MOSSAY, PAUL ALPHONSE, Chief Engineer, Nord Deutsche Maschinen & Armature Fabrik, Elek. Abtlg., Bremen, Ger. May 19, 1903

MOSSCROP, WM. A., *M.E.*, Electrical Engineer, 875 Sterling Pl., Brooklyn, N. Y. May 7, 1889

MOTT, FREDERICK ALLEN, Manager, Wheeler-Green Electric Co., Syracuse, N. Y. July 28, 1903

MOTT, WALTER, General Foreman, Phoenix Electric Co., Mansfield, Ohio. May 15, 1905

MOUNTAIN, JOHN THEODORE, Load-Despatcher, Chicago Edison Co., 139 Adams St.; res., 409 E. Huron St., Chicago, Ill. May 17, 1904

MOUSSELET, MARCEL EUGENE, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 29, 1907

MOWBRAY, WILLIAM J., Assistant Electrical Engineer, Narragansett Electric Lighting Co., Providence, R. I. Nov. 20, 1903

MOYER, JAMES AMBROSE, Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. July 26, 1907

MUDGE, ARTHUR LANGLEY, Allis-Chalmers-Bullock Ltd., Montreal, Can. Mar. 22, 1901

MUDGE, CHARLES A., Electrical Engineer, Railway Engineering Dept., General Electric Co., Schenectady, N. Y. Feb. 27, 1903

MUHLHEIZLER, LOUIS, Chief Engineer, Pittsburg and Allegheny Telephone Co.; Allegheny, Pa. Apr. 27, 1906

MUIRHEAD, JAMES, Assistant Designing Engineer, British Thomson Houston Co., Ltd., Rugby, England. May 21, 1907

MULLEN, THOMAS JAMES, Superintendent of Construction, Allis-Chalmers-Bullock, Ltd., Montreal, Que. Mar. 27, 1903

MULLER, ERNEST WELCH, Technical Assistant, C. O. Mailloux, 76 William St., New York City. Oct. 27, 1905

MÜLLER, HENRY NIKOLA, Electrician, Allegheny County Light Co.; res., 7217 Mt. Vernon St., Pittsburg, Pa. May 17, 1904

MULLIGAN, WALTER LYON, Manager, United Electric Light Co., Springfield, Mass. Feb. 28, 1902

MUNDY, AMBROSE, Marine Engine & Machine Co., 126 Liberty St., New York City. Jan. 23, 1903

MUNROE, GEORGE EGBERT, Electrical Engineer, 10 Avery St., Westfield, Mass. Feb. 23, 1906

MUNROE, WILL S., Superintendent of Wiring, Stone and Webster, 6th and Ohio Sts., Terre Haute, Ind. June 21, 1907

MURDOCK, HENRY DELOS, Superintendent, 52d St. Shop, B. R. T.; res., 682 Eastern Parkway, Brooklyn, N. Y. Jan. 23, 1903

MURGAS, JOSEPH, Inventor, 601 No. Main St., Wilkesbarre, Pa. Sept. 28, 1906

MURPHY, EDWARD MASON, Moscow, Idaho. Apr. 27, 1906

MURPHY, EDWIN J., Works Manager, Kelvin & Jas. White, Ltd., 18 Cambridge St., Glasgow, Scotland. Mar. 28, 1902

MURPHY, E. VERNON, 319 Equitable Bldg.; res., 2502 Madison Ave., Baltimore, Md. Aug. 17, 1904

MURPHY, FRANCIS HAYES, Professor of Electrical Engineering, Highland Park College, Highland Park, Des Moines, Ia. Apr. 26, 1907

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MURPHY, GEORGE R., Engineer, 2699 Union St., San Francisco, Cal. Apr. 25, 1902

MURPHY, JAMES EDWARD, Brooklyn Rapid Transit Co.; res., 8414 Fort Hamilton Ave., Brooklyn, N. Y. Dec. 28, 1906

MURPHY, JOHN Z., Chief Engineer, Chicago Union Traction Co.; res., 1943 Lexington St., Chicago, Ill. Sept. 25, 1903

MURPHY, PATRICK JOSEPH, Electrical Engineer, Ford, Bacon, and Davis 24 Broad St., New York City. Mar. 1, 1907

MURRAY, ALEXANDER EDMON, Electrical Engineer, 513 Calle Cuyo. Buenos Aires, Arg. Rep. Jan. 27, 1905

MURTY, HARRY ELIAS, Superintendent, Shamokin Light Heat and Power Co., Shamokin, Pa. June 21, 1907

MUSIL, LOUIS FREDERICK, H. L. Doherty and Co., 60 Wall St., New York City. Apr. 26, 1907

MUSSER, MARC JAMES, Engineering Department, Terra Hauta, Indianapolis & Eastern Traction Co., Terra Hauta, Ind. Mar. 1, 1907

MUSTARD, JOHN, Manager, Wagner Electric Mfg. Co., 1617 Real Estate Trust Bldg., Philadelphia, Pa. Apr. 22, 1904

MYERS, ALFRED RUSH, Electrical Engineer, Buffalo & Lake Erie Traction Co., Buffalo, N. Y. Jan. 29, 1904

MYERS, EARL COLMAN, Haenig Electric Co., Springfield, Ill. Mar. 1, 1907

MYERS, FREDERICK WILLIAM, Superintendent, Underground Cables, Allegheny Co. Light Company, Pittsburg, Pa. Sept. 26, 1902

MYERS, ROMAINE WRIGHT, Electrical Engineer, 3205, 14th St., Fruitvale, Cal. July 19, 1904

MYLER, PAUL JUDSON, Vice-president and General Manager, Canadian Westinghouse Co., Hamilton, Ont. Jan. 25, 1907

NACHOD, CARL PIVANY, President, United States Engineering Co., Room 614, 1929 Chestnut St., Philadelphia, Pa. Mar. 29, 1907

NAGEL, WILLIAM G., President and Manager, The W. G. Nagel Electric Co., 28 St. Clair St., Toledo, Ohio. Feb. 27, 1903

NAMBA, M., Professor of Electrical Engineering, University of Kioto, Kioto, Japan. Apr. 26, 1899

NAPHTALY, SAM L., Asst. Engineer, San Francisco Gas & Electric Co., 1770 Pacific Ave., San Francisco, Cal. Aug. 23, 1899

NASH, LUTHER ROBERTS, Electrical Engineer, Stone & Webster Engineering Corporation, 147 Milk St., Boston, Mass. Mar. 27, 1903

NATH, BANGALORE DVARAKA, Bangalore City, British India. Mar. 25, 1904

NATHAN, WILFRED McDOWELL, Electrician, United States Gypsum Co., Oakfield, N. Y. Mar. 29, 1907

NAUCLER, RHEINHOLD, Electrical Engineer, 4 Mosebacketorg, Stockholm, Sweden. July 28, 1903

NAUTRE, LOUIS CHARLES FEUILLIARD, Test Expert, with Morton Havens, Jr., 79 Chapel St., Albany, N. Y. Apr. 27, 1906

NEALL, NEWITT JACKSON, Consulting Electrical Engineer, 12 Pearl St., Boston; res., 73 Cedar St., Roxbury, Mass. Oct. 23, 1903

NEEL, ASHBEL, CALOWAY, Jackson, Gas Light Co., Jackson, Miss. Sept. 22, 1905

NEELY, JOHN CROSBY, Electrical Engineer, The Arnold Co., Borland Bldg., 181 La Salle St., Chicago, Ill. Nov. 24, 1905

NEILSON, JOHN, Consulting Electrical Engineer, Bates & Neilson, 42 Broadway, New York City; res., Larchmont, N. Y. May 18, 1897

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NESBIT, ARTHUR FLEMING, Professor of Physics and Electrical Engineering, New Hampshire College, Durham, N. H. Jan. 25, 1907

NEIMAN, WILLIAM FRANKLIN, Power Solicitor, San Francisco Gas and Electric Co., San Francisco, Cal. June 21, 1907

NESBIT, JOSEPH NEWTON GRAY, Professor, Dept. Experimental Engineering, Georgia School of Technology, Atlanta, Ga. Nov. 22, 1901

NESBIT, WILLIAM, Electrical Engineer, Westinghouse E. & M. Co., 11 Pine St., New York City. Oct. 24, 1902

NEURATH, MORRIS M., Electrical Engineer, Room 603, 87 Nassau, St., N. Y. Feb. 28, 1900

NEVITT, IRVING HEWARD, Tester, 46 Bloor St., W. Toronto, Ont. Apr. 28, 1905

NEWBOLD, ROGER MERRICK, Electrical Engineer, Adams and Westlake Co., 110 Ontario St., Chicago, Ill. June 21, 1907

NEWBERY, JORGE, General Director, Electrical Works and Public Lighting, 350 Moreno, Buenos Aires, A. R. Nov. 25, 1904

NEWBURY, F. J., Manager, Insulated Wire Department, John A. Roebling's Sons Co., Trenton, N. J. Sept. 23, 1896

NEWCOMB, ROBERT COOK, Pensacola Electric Co., Pensacola, Fla. Sept. 28, 1906

NEWELL, FRANK CLARENCE, Mutograph Corporation, Citizen's Building, Cleveland, Ohio. Jan. 3, 1902

NEWELL, FRANK LORD, Electrical Engineer, 1 Madison Ave., New York City. Mar. 27, 1903

NEWELL, FREDERICK WILLIAM, Assistant Electrical Engineer, Otis Elevator Co., Philadelphia, Pa. Nov. 21, 1902

NEWELL, HARVEY EDGAR, India Rubber and Gutta Percha Insulating Co.; res., 11 Lincoln Terrace, Yonkers, N. Y. Sept. 25, 1903

NEWMAN, MORTIMER LEWIS, Master Electrician, Department of Yards and Docks, Navy Yard, New York City. Apr. 22, 1904

NEWMAN, LEROY L., Inspector, Pennsylvania Railroad Co., 314 Delaware Ave., N. E., Washington, D. C. Mar. 29, 1907

NEWTON, HENRY CLEMENT, Manager, British Insulated & Helsby Cables, Ltd.; res., 493 Collins St., Melbourne, Australia. Sept. 28, 1906

NEWTON, NED EARNEST, Engineer, Western Electric Co., 463 West St., New York City. Dec. 18, 1903

NEWTON, SAMUEL OSCAR, North Pitcher, N. Y. Sept. 25, 1903

NEXSEN, RANDOLPH HALLIDAY, Electrical Engineer, 34 Beekman St., New York City; res., 302 St. James Pl., Brooklyn, N. Y. Nov. 21, 1902

NICHOLS, CHARLES KETCHAM, Agent, New York Edison Co., 55 Duane St.; res., 706 Union St., Brooklyn, N. Y. Apr. 23, 1903

NICHOLS, CHARLES STEARNS, Electrical Engineer, Topaz Mining Co., Bluefields, Nicaragua, C. A. Mar. 24, 1905

NICHOLS, GEORGE BROWN, Electrical Draughtsman, Board of Education, Park Ave., and 59th St., New York City. Apr. 26, 1907

NICHOLS, LOUIS CHARLES, Electrical Engineer, 2267 Jefferson Ave., South Norwood, Ohio. Feb. 28, 1902

NICHOLSON, CHARLES MARION, Engineer, Test Dept., Bullock Electric Mfg. Co., Cincinnati, Ohio. Jan. 23, 1903

NICHOLSON, LLOYD CARLTON, Iroquois Construction Co., Fidelity Bldg., Buffalo, N. Y. May 17, 1904

NICHOLSON, SAMUEL L., Manager Industrial and Power Dept., Westinghouse Elec. & Mfg. Co., Pittsburg, Pa. July 26, 1900

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NICOLL, GEORGE D., Indianapolis and Cincinnati Traction Co., Rushville, Ind. Mar. 27, 1903

NIELSEN, AXEL, Inspector, Westinghouse Electric and Mfg. Co., 517 Fidelity Building, Buffalo, N. Y. Apr. 26, 1907

NIELSEN, JULIAN JACOB, Draughtsman, J. L. Schureman Co.; res., 649 Irving Park Blvd., Chicago, Ill. Dec. 28, 1906

NIES, JOHN DERK, Instructor, Lewis Institute, Chicago, Ill. Feb. 24, 1905

NIESZ, HOMER ELDREDGE, Assistant to Second Vice-president, Chicago Edison Co., 139 Adams St., Chicago, Ill. Oct. 25, 1901

NIETHAMMER, FREIDRICH, Professor of Electrical Engineering Technische Hochschule, Brünn, Austria. Feb. 27, 1903

NICKELS, CHARLES BURTON, Assistant to General Manager, Toledo Gas, Electric and Heating Co., Toledo, O. Mar. 1, 1907

NIKONOW, JOHN PAUL, Engineering Department, Westinghouse Electric Co., Pittsburg, Pa. Mar. 14, 1906

NILES, ELIOT WRIGHT, Engineering Department American Telephone & Telegraph Co., 15 Dey St., New York City. Feb. 23, 1906

NIMIS, ALBERT A., Electrical Contractor, Nimis & Nimis, 314 Madison Ave., New York City. Aug. 13, 1897

NIMS, FREDERICK D., Chief Operating Engineer, Mexican Light ard Power Co., Mexico City, D. F. Mex. Jan. 25, 1907

NISHIKAWA, KIKEI, 8 Kagwiaoka, Yoshida St., Kyoto, Japan Apr. 22, 1904

NISHIZAKI, SUMIO, Chief Electrical Engineer, Furukawa Mine Bureau, Katsuno Chikuzen, Japan. Sept. 28, 1906

NIXON, GEORGE, Copartner, Nixon and Kimmel, 327 Wall St., Spokane, Wash. June 21, 1907

NOBLE, GROVER CHESTER, Assistant in Electrical Engineering, University of California, Mechanics' Building, Berkeley, Cal. Dec. 19, 1902

NOBLE, GUY HINCHMAN, Salesman, Stanley, G. I. Electric Mfg. Co., 42 Broadway, New York City; res., Somerville, N. J. July 19, 1904

NOBLE, IRVINE MORRISON, Operating Department, Gould Storage Battery Co.; 341 Fifth Ave., New York City. Apr. 26, 1907

NOBLE, JOHN HINCHMAN, 232 West 131st St., New York City. Mar. 24, 1905

NODELL, WILLIAM LEON, Student, Brooklyn Polytechnic Institute; res., 243 South 4th St., Brooklyn, N. Y. Jan. 25, 1907

NOE, JAMES BRYAN, The New York Edison Co., 55 Duane St., New York City; res., 29 Elm St., Elizabeth, N. J. June 19, 1903

NOEGGERATH, JACOB EMIL, Engineer, General Electric Co.; res., 409 Union St., Schenectady, N. Y. Mar. 27, 1903

NORBERG, SVEN, Electrical Engineer, Allmanna Svenska, Elektriska, Aktiebolaget, Westeras, Sweden. Feb. 24, 1905

NORCROSS, ARTHUR FLOYD, 704 Westover Ave., Schenectady, N.Y. Apr. 26, 1907

NORDSTRUM, LAUREN DALE, Electrical Engineer, Engineering Dept. Ft. Wayne Electric Works, Ft. Wayne, Ind. Oct. 28, 1904

NORRIS, MARVIN L., Draftsman, Fort Wayne Electric Works, Fort Wayne, Ind. June 21, 1907

NORTH, GILBERT, Electrical Engineer, British Westinghouse E. & M. Co. Trafford Park, Manchester, Eng. Sept. 25, 1903

NORTHMORE, EMANUEL RICHARD, Superintendent, Los Angeles Gas and Electric Co., Los Angeles, Cal. Apr. 26, 1907

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NORTHRUP, EDWIN FITCH, The Leeds & Northup Co., 4901 Stenton Ave., Philadelphia, Pa. Sept. 27, 1901

NORTHRUP, EDWIN S., Electrical Draftsman, Municipal Building, 3d Ave. & 177th St., New York City. Sept. 28, 1906

NORTON, WILLIAM JOHN, Manager, Malcolm W. Hill Co., 317 W. 42d St., New York City. May 17, 1904

NOTOMI, IWAICHI, Chief Engineer, Electrical Designing Department, Shibaura Engineering Works, Shibaku, Tokyo, Japan. Dec. 18, 1903

NOTT, ELIPHALET, Foreman Sub-station, Interborough Rapid Transit Co., New York City. Apr. 27, 1906

NOWELL, JOHN CHASE, Superintendent of Plant, Bell Telephone Co., 17th and Filbert Sts., Philadelphia, Pa. Apr. 26, 1907

NOWLAN, EDWARD ALONZO ROSSEAU, Telephone Engineer, Western Electric Co., 259 South Clinton St., Chicago, Ill. June 21, 1907

NOWLAN, BRETE CASSIUS, Installation Department, Western Electric Co., Chicago, Ill.; res., Havelock, Ia. Mar. 29, 1907

NOXON, C. PER LEE, Manufacturer, High-Frequency X-Ray Apparatus, Dynamos & Motors, 500 E. Water St., Syracuse, N. Y. Oct. 17, 1894

NOYES, ERNEST HIGH, Manager of Chicago Office, The Pittsburg Reduction Co., 158 La Salle St., Chicago, Ill. Sept. 25, 1903

NOYES, FRANK ALBERT, Assistant Electrical Engineer, Rio Janeiro Light and Power Co., Rio Janeiro, Brazil. Apr. 26, 1907

NUNN, RICHARD J., *M. D.*, 5 York St. East, Savannah, Ga. July 12, 1887

NURIAN, KERSON, Engineering Department, Missouri Pacific Railway Building, St. Louis, Mo. May 17, 1904

NUTTER, COLEMAN EVAN, Electrical Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kan. Apr. 28, 1905

NUTTER, EDWARD HOIT, Assistant Superintendent, Liberty Bell Mine Telluride, Col. Feb. 23, 1906

NYE, RALPH DOUDNA, Correspondent, Westinghouse Electric and Mfg. Co., New England Building, Cleveland, Ohio. Sept. 28, 1906

NYHAN, J. T., Superintendent and Electrician, Macon Electric Light and Railway Co., Macon, Ga. Feb. 27, 1895

OAKMAN, HENRY B., Sales Engineer, Bullock Electric Co., 39 Cortlandt St., New York City; res., Linden, N. J. June 21, 1907

OBEAR, GEORGE BARROWS, Instructor in Mathematics, Brown University, Providence, R. I. Nov. 20, 1903

O'BEIRNE, EDWARD, J. Contracting Engineer, 201 Cotton Exchange Building, New Orleans, La. Sept. 28, 1906

O'BRIEN, ALBERT DALLAM, Weed Manufacturing Co., Wilmington, N. C. Nov. 22, 1901

O'BRYAN, FRANCIS L., Asst. to Electrical Engineer, Boston, and Worcester Street Railway Co., South Framingham, Mass. Jan. 27, 1905

OCHS, SAMUEL O., 355 Boylston St., Boston, Mass. May 15, 1905

ODELL, THOMAS GARLAND, Western Electric Co.; res., 856 W. Jackson Boulevard, Chicago, Ill. Jan. 26, 1906

O'DONOVAN, LEO J., Consulting Engineer, Reis & O'Donovan, 1123 Broadway; res., 268 West 91st St., New York City. Apr. 25, 1902

OESTERREICHER, SANDOR, IGNATI, Electrical Draftsmen, New York Edison Co., New York City Mar. 1, 1907

O'FARRELL, RICHARD WILLIAM, Clerk, Cordoba Electric Light and Power Co., Cordoba, Argentine Republic. June 21, 1907

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OFFUTT, ANDERSON, *B.S.*, *E.E.*, Electrician, Barnes-Offutt, Construction Co., Ltd., 634 Gravier St., New Orleans, La. May 15, 1900

OFVERHOLM, IVAN, Electrical Engineer, Swedish State Railways, Dalagatan 56 A, Stockholm, Sweden. Feb. 23, 1906

OGDEN, KARL RANDALL, Field Engineer, Central District and Printing Telegraph Co., Pittsburg, Pa. Dec. 28, 1906

OGLE, JOHN HOWARD, Electrical Engineer, Bell Telephone Co., 3844 Olive St., St. Louis, Mo. Mar. 25, 1904

O'HERN, JAMES HENRY, JR., Phoenix Iron Works, 1011 Walnut St., Boulder, Colo. Mar. 24, 1905

OI SAITARO, Chief Engineer to the Bureau of Posts and Telegraphs, The Ministry of Communications, Tokyo, Japan. Dec. 28, 1898

OKEY, PERRY, Superintendent, Columbus Municipal Electric Light Plant; res., 89 West Ave., Columbus, Ohio. Apr. 23, 1903

OLDHAM, WILL HAROLD, Draughtsman, Electrical Department, Cambria Steel Co., Johnstown, Pa. Oct. 23, 1903

OLHEISER, WILLIAM WEAVER, General Supt., Eastern Telephone & Telegraph Co., 3d and Federal Sts., Camden, N. J. Apr. 23, 1903

OLIN, EDWIN MASON, Engineer Foreman in charge Testing Department Westinghouse E. &. M. Co., Pittsburg, Pa. Feb. 27, 1903

OLIVETTI, CAMILLO, Ingegnere Industriale, Ivrea, Italy. Oct. 17, 1892

OLMSTED, ELMER SHERIDAN, Electrical Assistant Boston Elevated Ry. Co., 552 Harrison Ave., Boston, Mass Sept. 28, 1906

OLMSTEAD, HARRY WILLIAM, Electrical Inspector, with Fremont Wilson, Hackensack, N. J. May 19, 1903

OLNEY, WILLIAM MAIRS, Ass't. to Division Equipment Engineer, N. Y. and N.J. Tel. Co., 409 Clinton Ave., Brooklyn, N. Y. Jan. 25, 1907

OOLGAARDT, J. J., Electrical Engineer (Foreign Dept.), General Electric Co.; res., Edison Hotel, Schenectady, N. Y. Apr. 25, 1900

ORBELL, ROBERT HUGH, Adams Mfg. Co., Ltd., Bedford, Eng. May 20, 1902

ORBIN, FRANK, Carnegie Technical School, Schenley Park, Pittsburg Pa. Jan. 23, 1903

O'REILLY, ANDREW J., President, Board of Public Improvements, 1507 Papin St., St. Louis, Mo. Apr. 23, 1903

ORMSBEE, ALEX. F., Electrical Engineer, with N. Y. and N. J. Telephone Co., 81 Willoughby St., Brooklyn, N. Y. June 27, 1895

ORR, HARRY ALLEN, President, Savannah River Power Co., Anderson, S. C. Mar. 25, 1904

OSBORN, HAROLD, Arthur Frantzen, 92 W. Van Buren St., Chicago, Ill. Oct. 28, 1904

OSBORN, JOSEPH AUGUSTUS, Electrical Engineer, American Car & Foundry Co., Lincoln Trust Bldg., St. Louis, Mo. Apr. 27, 1906

OSBORNE, GEORGE FREDERICK FOLGER, 221 George St., Toronto, Can. Mar. 27, 1903

OSBORNE, IRVING H., Electrical Draughtsman, Newport News Shipbuilding and Dry Dock Co., Newport News, Va. June 14, 1905

OSBORNE, LOYALL ALLEN, Manager of Works, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Oct. 18, 1893

OSBORNE, MARSHALL, Engineer, 10 St. Peters Road, Harbourne, Birmingham, Eng. Apr. 25, 1900

OSCHMANN, WILLIAM OLIVER, Electrical Engineer, Oliver Iron & Steel Co., Pittsburg, Pa. Jan. 25, 1907

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OSGOOD, Farley, General Superintendent Distribution, P. S. C. of N. J., 207 Market St., Newark St., N. J. June 14, 1905

OSGOOD, HARRY WHITNEY, Assistant Electrical Engineer, Stone and Webster, 84 State St., Boston, Mass. June 21, 1907

OSGOOD, ISAAC, Inspector, Underwriters Bureau of New England; 93 Water St., Boston, Mass. Apr. 26, 1907

O'SHEA, John Edmund, Assistant Superintendent, Waterbury & Co., 42 Graham St., Brooklyn, N. Y. Feb. 24, 1905

OSHIMA, HIROYOSHI, Electrical Engineer, Osaka Electric Light Co., Osaka, Japan. Apr. 28, 1905

OSKAMP, HOWARD EARL, Standard Electric Construction Co., Rochester, N. Y. Feb. 23, 1906

OSTHOFF, OTTO EARNEST, Electrical Engineer, H. M. Byllesby & Co., 420 New York Life Building, Chicago, Ill. May 17, 1904

OSWALD, HERMAN HENRY, Hudson River Elec. Power Co., Glens Falls, N. Y. Nov. 20, 1903

OTAKI, TEISHIRO, Suiriiimucho, Kyoto, Japan. May 14, 1906

OTIS, HENRY BAILY, Manager, Cutter Electrical and Mfg. Co., 636 Marquette Bldg., Chicago, Ill. Apr. 26, 1907

OTTEN, DR. JAN D., Director, Batavia Electrische Tram-Maatschappij, Heerenqracht, 259 Amsterdam, Holland. Nov. 18, 1890

OTTO, FREDERICK ARTHUR, Asst. Superintendent, St. Paul Gas Light Co., 1064 Hague Ave., St. Paul, Minn. Oct. 26, 1906

OVIATT, WESLEY THORNTON, General Superintendent, Narragansett Electric and Lighting Co., Providence, R. I. Apr. 27, 1906

OVINGTON, EARLE LEWIS, President, Ovington Motor Co., 2234 Broadway New York City. Apr. 22, 1904

OWEN, LLEWELYN, Assistant Supt., Peoria Gas and Electric Co.; res., 407 Ellis St., Peoria, Ill. Nov. 25, 1904

OWEN, PERCY THOMAS, Inspector General of Works, Commonwealth Offices, Russel St., Melbourne, Australia. Aug. 17, 1904

PACKARD, LEONARD WARREN, Assistant Engineer of Meter Department, General Electric Co., Lynn, Mass. Apr. 23, 1903

PAGE, A. D., Assistant Manager, General Electric Co. Lamp Works, Harrison, N. J. Jan. 19, 1892

PAGE, ERNEST FREDERICK, Electrician, Corporation Electric Light Wks.; res., 6 Kelvin St., Gardens, Cape Town, S. A. Sept. 22, 1905

PAHL, AUGUST JULIUS, with California Gas & Electric Corp., 1121 E. Miner Ave., Stockton, Cal. Dec. 23, 1904

PAINE, ELLERY BURTON, [*Local Secretary*], Asst. Prof. Elec. Engineering, University of Illinois, Urbana, Ill. Aug. 17, 1904

PAINTER, GEORGE M., Contractor, 77 Jackson Blvd., Chicago, Ill. Sept. 28, 1906

PALMER, ALBERT NICKERSON, Electrical Engineer, Phillips Insulative Wire Co., Pawtucket, R. I. Dec. 28, 1906

PALMER, AUSTIN PHELPS, Student, Columbia University, New York; res., 216 Clinton Ave., Brooklyn, N. Y. Aug. 25, 1905

PALMER, D, ALONZO, Superintendent, Compania Anonima de Redes Telefonicas de Ponce; Ponce, Porto Rico. Oct. 25, 1901

PALMER, HARRY MITCHELL, Mechanical and Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

PALMER, LEW RUSSEL, Assistant Electrical Superintendent, Jones and Laughlin, Steel Co.; Pittsburg, Pa. Sept. 28, 1906

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PALMER, RAY, Secretary, Hendel Wire Brush Co., 317 Milwaukee St., Milwaukee, Wis. Sept. 22, 1905

PALMER, WILLIAM HENRY, JR., Electrical Engineer & Asst. to President, N. Y. Transp. Co., 815 8th Ave., New York City. May 20, 1902

PANTER, THOMAS ALFRED, Ontario Power Co., Ontario, Cal. Sept 25, 1903

PARDEE, HARVEY SABIN, I. W. D. Dept., John A. Roeblings Sons Co., Trenton, N. J. Jan. 25, 1907

PARK, ALBERT E., General Manager, Des Moines Winteser and Creston Elec. Railway Co., Des Moines, Iowa. Oct. 26, 1906

PARK, HENRY BIGHAM, General Electric Co.; res., 7 N. College St., Schenectady, N. Y. June 14, 1905

PARKE, ROBERT AUGUSTUS, Special Agent, Westinghouse Air Brake Co., 634 Endicott Building, St. Paul, Minn. Jan. 23, 1903

PARKE, RODERICK J., Consulting Electrical Engineer, 52 Janes Building, Toronto, Can. July 26, 1900

PARKER, HERSCHEL C., Adj. Prof. of Physics, Columbia University, New York City; res., 21 Fort Greene Pl., Brooklyn, N. Y. Apr. 19, 1892

PARKER, HOMER CHARLES, Salesman, Stanley G. I. Electric Mfg. Co., 69 New Montgomery St., San Francisco, Cal. Sept. 25, 1903

PARKER, JOHN CASTLEREAGH, 34 Clinton Ave., North, Rochester, N. Y. Aug. 17, 1904

PARKER, LINDSAY R., 345 State St., Brooklyn, N. Y. Sept. 27, 1901

PARKER, RALZEMOND DRAKE, Instructor in Electrical Engineering, University of Michigan, Ann Arbor, Mich. Jan. 25, 1907

PARKHURST, CHARLES WILLIAM, Superintendent of Electrical Department, Cambria Steel Co., Johnstown, Pa. Sept. 27, 1901

PARKIN, FREDERICK JAMES, Construction Foreman, Canadian General Electric Co.; res., 857 King St. W., Toronto, Ont. Feb. 26, 1904

PARKS, COLEMAN CLYDE, Stone and Webster Engineering Corp., Terra Haute Savings Bank Bldg., Terra Haute, Ind. Oct. 23, 1903

PARMLY, C. HOWARD, *S.M., E.E.*, College of the City of New York, 17 Lexington Ave., New York City. Feb. 21, 1893

PARODI, HIPPOLYTE, Engineer, 10 Rue de Londres, Paris, France. Sept. 26, 1902

PARROTT, ROBERT PARKER, Electrical Expert, Grey National Telautograph Co., New York City. Aug. 17, 1904

PARRY, EVAN, Engineer H. F. Parshall, Salisbury House, London Wall, London, Eng. Sept. 25, 1895

PARRY, RICHARD W., Chief Engineer, Scioto Valley Traction Co.; res., 293 Rienhard Ave., Columbus, O. May 14, 1906

PARSELL, HENRY V. A., Electrical and Mechanical Designing and Experimental Work, 129 W. 31st St., New York City. Nov. 12, 1889

PARSHALL, AUGUST, Commercial Engineer, Supply Dept., General Electric Co., 44 Broad St., New York City. Oct. 24, 1900

PARSONS, CHARLES EDWARD, Chief Engineer, Hudson River Electric Power Co., 82 State St., Albany, N. Y. June 14, 1905

PARSONS, GEORGE, Secretary, Smith Improved Lock Nut Co., Inc., Rockford, Ill. Dec. 15, 1905

PARSONS, PHILIP DOUGLAS, Telephone Engineer, Western Electric Co., 463 West St., New York City. June 21, 1907

PARTRIDGE, WARREN, Public Service Corporation of New Jersey, 207 Market St., Newark, N. J. Nov. 25, 1904

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PATERSON, FREDERICK WILLIAM, Sales Engineer, Stanley Electric Mfg. Co.; res., 39 Dalton Ave., Pittsfield, Mass. Mar. 24, 1905

PATTEN, GEORGE HOLMES, President, Truxal-Painter Mfg. Co., Chattanooga, Tenn. Apr. 27, 1906

PATTERSON, EDWARD GEORGE, General Superintendent, Canadian General Electric Co., Peterborough, Ont. Feb. 24, 1905

PATTERSON, GEORGE WASHINGTON, Professor of Electrical Engineering, University of Mich., Ann Arbor, Mich. Sept. 27, 1901

PATTERSON, HAROLD D., Consulting Engineer, 55 Liberty St., New York City. Mar. 27, 1903

PATTERSON, WILLIAM HART, JR., Westinghouse Electric & Mfg. Co., Pittsburg; res., 440 South Ave., Wilkinsburg, Pa. July 28, 1905

PATTISON, HUGH, Electrical Engineer, with George Gibbs, 10 Bridge St.; New York City. Sept. 25, 1903

PATTON, WILLIAM FEARN, JR., Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 28, 1906

PAUL, EARL WHEELER, Electrical Engineer, Duquesne Light Co.; res., 219 Swissvale Ave., Pittsburg, Pa. July 26, 1907

PAULY, KARL ALMON, Engineer, General Electric Co.; res., 1 Division St., Schenectady, N. Y. May 19, 1903

PAYNE, ROBERT PRESTON, Salesman, Northern Electrical Co., Minneapolis, Minn. Apr. 27, 1906

PEAKER, WILLIAM JAMES, Draftsman, Lake Superior Power Co., Saulte Ste Marie, Ont. Mar. 1, 1907

PEARSON, ALBERT L., Assistant, Lockwood, Greene and Co., 93 Federal St., Boston, Mass. Mar. 29, 1907

PEARSON, EDWIN RICHTER, Electrical Engineer, Transformer Department, General Electric Co., Schenectady, N. Y. Sept. 28, 1906

PEARSON, JOHN, Superintendent St. Croix Power Co., Somerset, Wis. Sept. 26, 1902

PEASE, HAROLD CHILDS, Engineer, General Electric Co.; res., 820 Union St., Schenectady, N. Y. Mar. 27, 1903

PEASE, HENRY MARK, Telephone Engineer, The Western Electric Co., No. Woolwich, E., London, Eng. May 19, 1903

PEASE, LEWIS ADAMS, Designing Engineer, Chicago and Milwaukee Electric Railroad Co.; res., Highwood, Ill. June 21, 1907

PECK, ASHLEY POMEROY, Salesman, Allis-Chalmers Co., New York City. Aug. 17, 1904

PECK, EDWARD F., Manager, Lighting and Power Dept., Schenectady Railway Co., 420 State St., Schenectady, N. Y. May 20, 1890

PECK, HENRY WATERMAN, Electrical Engineer, Consolidated Gas Electric Lt. & P. Co., 30 S. Eutaw St., Baltimore, Md. Dec. 23, 1904

PECK, RANSOM B. W., Electrician, Kingsbridge Power Station, N. Y. City Ry., 96th St. and East River, New York City. Sept. 25, 1903

PEDDRICK, CHARLES HENRY, JR., Manager, Light and Power Department, Hudson River Electric Power Co., Glens Falls, N. Y. Mar. 29, 1907

PEILER, KARL ERNST, Electrical Engineer with W. S. Barstow, 56 Pine St., New York City. Apr. 27, 1906

PEIRCE, ALBERT EDWIN, JR., Power and Mining Department, General Electric Co., 706 Phœnix Bldg., Minneapolis, Minn. Feb. 26, 1904

PENDELL, CHAS. WILLIAM, North Shore Electric Co., Chamber of Commerce, Chicago, Ill. Nov. 22, 1899

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PENDER, HAROLD, Assistant, Cary T. Hutchinson, 60 Wall St., New York City; res., Perth Amboy, N. J. May 14, 1906

PENNEBAKER, EDWIN PRESTON, 1015 Division Ave., Tacoma, Wash. Jan. 23, 1903

PENNEFATHER, WILFRED ERNEST, Engineer, Mount Bischoff Tin Mining Co., Reg., Waratah, Tasmania. Feb. 23, 1906

PENNELL, WALTER Otis, Chief Engineer, Missouri & Kansas Telephone Co.; res., 901 Benton Blvd., Kansas City, Mo. Nov. 24, 1905

PEREZ, MARCIAL, Acting Manager, Light and Power Dept., Manila Electric Railroad and Light Co., Manila, P. I. Aug. 25, 1905

PERKINS, HENRY A., Professor of Physics, Trinity College; res., 55 Forest St., Hartford, Conn. July 28, 1903

PERKINS, THOMAS STEEL, Electrical Engineer, Westinghouse Electric Mfg. Co., Pittsburg. Apr. 28, 1905

PERRY, ALEXANDER, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City. June 15, 1904

PERRY, CHARLES LANGDON, Designing Engineer, General Electric Co.; res., No. 1 State St., Schenectady, N. Y. Mar. 27, 1903

PERRY, JAMES WILLIAM, Manager Electric Department, H. W. Johns, Manville Co., 100 William St., New York City. Apr. 23, 1903

PERRY, LUTHER PACKARD, Superintendent, Fries Mfg. and Power Co., Winston-Salem; res., Clemmons, N. C. June 21, 1907

PESTELL, FREDERICK J., Assistant Engineer, J. G. White & Co., 43 Exchange Pl., New York City. Apr. 28, 1905

PETERS, CHARLES SUMNER, Assistant Engineer, Wagner Electric and Mfg. Co., St. Louis, Mo. Nov. 23, 1906

PETERSEN, OLUF GOTTLIEB, Electrical and Mechanical Engineer, Stearns Lumber Co., Stearns, Ky. Oct. 28, 1904

PETERSEN, PETER CONRAU, 19 John St., Muskegon, Mich. Dec. 28, 1906

PETERSON, JESSE, President and Manager, United Insulated Fibre Co., Lockport, N. Y. Apr. 26, 1907

PETICOLAS, SHERMAN GOODWIN, Sales Representative, Westinghouse E. & Mfg. Co., 1218 Farnam St., Omaha, Neb. Sept. 27, 1901

PETTY, HERBERT CLINTON, Assistant in Sales Department, Crocker-Wheeler Co., Ampere; res., East Orange, N. J. June 19, 1903

PETTY, WALTER M., Superintendent Fire Alarm Telegraph, Rutherford, N. J. May 16, 1893

PETURA, FRANK JOSEPH, Member of Experimental Corps, Denver Gas and Electric Co., Denver, Colo. Jan. 25, 1907

PFATISCHER, MATHIAS, Chief Engineer, The Electro-Dynamic Co., of Philadelphia, Philadelphia, Pa. Apr. 23, 1903

PFUND, RICHARD, Engineer, 600 West 146th St., New York City. Apr. 18, 1893

PHELON, JOSEPH OLIVER, Assistant Professor of Electrical Engineering, Worcester Polytechnic Institute, Worcester, Mass. Mar. 27, 1903

PHELPS, CHARLES E., JR., Chief Engineer, City of Baltimore Electrical Commission, Baltimore, Md. Jan. 27, 1905

PHENICIE, CARROLL RUBICAM, Electrical Engineer, Chicago & Milwaukee Electric R. R., Highwood, Ill. Sept. 28, 1906

PHILIP, ROBERT ASHBY, Engineering Dept., Stone & Webster Engineering Corporation, 147 Milk St., Boston, Mass. May 14, 1906

PHILLIPS, CHARLES TRAVERS, Wiring and Construction Dept., Seattle Electric Co., Seattle, Wash. Apr. 27, 1906

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PHILLIPS, EDWIN TERRY, Electrical Superintendent, P. N. Y. and L. I. R. R. Co., 4th and Front Sts., Long Island City, N. Y. Feb. 23, 1906

PHILLIPS, ELLIS LAURIMORE, Engineer, 45 Broadway; res., 11 West 103d St., New York City. Mar. 28, 1902

PHILLIPS, IRVING WADSWORTH, Superintendent of Power Plant, North Mountain Power Co., Junction City, Cal. Apr. 22, 1904

PHILLIPS, LEO A., Westinghouse Machine Co., Westinghouse Bldg., Pittsburg, Pa. Mar. 21, 1894

PHILLIPS, THOMAS LODGE, Superintendent, Genesee County Electric Light, Power and Gas Co., Batavia, N. Y. Nov. 23, 1906

PHILLIPS, WALTER, Westinghouse Brake Co., Ltd., 82 York Road, King's Cross, London, Eng. Feb, 27, 1903

PHILPOT, LAWRENCE BENJAMIN, Operator at Generating Station, Vancouver Power Co., Vancouver, B. C. Sept. 28, 1906

PHINNEY, ROBERT MORRIS, with Signal Engineer, Illinois Central R. R. Chicago, Ill. Mar. 29, 1907

PIATT, WILLIAM MCKINNEY, J. L. Ludlow, Winston-Salem, N. C. Oct. 27, 1905

PICKARD, GREENLEAF WHITTIER, Electrical Engineer, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Mar. 27, 1903

PICKHARDT, HARRY LOUIS, Sales Department, Holophane Co., Chicago, Ill. Feb. 24, 1905

PIEK, STEFAAN, Niagara, Lockport and Ontario Power Co., 814 Fidelity Building, Buffalo, N. Y. Apr. 27, 1906

PIERCE, ALFRED LAWRENCE, Superintendent, General Manager and E. E. Borough Electric Works, Wallingford, Conn. Mar. 28, 1902

PIERCE, GEORGE ALBERT, JR., Assistant Supt. of Electrical Department William Cramp & Sons, Philadelphia, Pa. May 19, 1903

PIERCE, LONNIE JOHN, Electrical Engineer, American Window Glass Co., Room 1624, Farmers Bank Bldg., Pittsburg, Pa. Jan. 27, 1905

PIERSON, HENRY, Electrical Engineer, British Westinghouse Electric and Mfg. Co.; Trafford Park, Manchester, Eng. Mar. 29, 1907

PIERSON, HENRY GREGORY, Foote, Pierson & Co., 160 Duane St., New York City; res., 246 Turrell Ave., So. Orange, N. J. May 17, 1904

PIETCZKER, EZRA JAMES, S. W. Manager, Standard Underground Cable Co., 521 Security Bldg., St. Louis, Mo. Apr. 23, 1903

PIETSCH, JAMES ANDERSON, Chief Engineer, Esperanza Central Sugar Co., Naguabo, Porto Rico. May 19, 1903

PIKE, DANIEL ELVIN, Operator, Western Union Telegraph Co., New York City. Jan. 25, 1907

PILCHER, JOHN WILLIAM, Salesman, Canadian General Electric Co., Halifax, N. S. May 15, 1905

PILLSBURY, CHAS. L., Claussen, Burch & Pillsbury, Consulting Engineers, 514 Ger. Amer. Bank Bldg., St. Paul, Minn. Aug. 13, 1897

PINCKNEY, THEOPHILUS, Chief Engineer, Asheville Electric Co.; res., 169½ Patton Ave., Asheville, N. C. June 21, 1907

PINKLEY, ROY HENRY, Chief Draughtsman, Union Electric Light and Power Co.; res., 4163a Russell Ave., St. Louis, Mo. June 14, 1905

PINSON, EMILE, General Manager Cia Explobadora de las Fuerra Hydro Electricas de San Ildefonso, Mexico City, Mex. June 19, 1903

PIRELLI, ALBERTO, Managing Director, Pirelli & Co., Milan, Italy. Sept. 22, 1905

PIRTLE, CLAIBORNE, Electric Controller and Supply Co.; res., 29 Olive St., Cleveland, O. Mar. 28, 1902

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PITCHER, FRANK HENRY, Chief Engineer, Montreal Water and Power Co., 62 Imperial Building, Montreal, P. Q. June 28, 1901

PIXLEY, MILTON ADOLPHUS, Superintendent of Construction, Erner-Hopkins Co.; res., 477 Linwood Ave., Columbus, O. Feb. 26, 1904

PIZZINI, ANDREW J., General Manager, Electric Construction Co., of Virginia, Richmond, Va. Aug. 22, 1902

PLACE, CLAUDE W., Electrical Engineer, General Electric Co.; res., 118 Park Ave., Schenectady, N. Y. Nov. 23, 1906

PLAISTED, ARTHUR I., Engineering Inspector, Metropolitan Water and Sewer Board; res., 17 Franklin St., Somerville, Mass. Apr. 22, 1904

PLANK, DAVID HORACE, Electrical Engineer, General Electric Co.; res. 135 Barrett St., Schenectady, N. Y. Nov. 23, 1906

PLATT, FREDERICK, Electrical Engineer, General Electric Co., Lynn, res., Cliftondale, Mass. Nov. 24, 1905

PLATT, NATHANIEL, Inspection Department, New York Edison Co., res., 2 E. 127th St., New York City. Aug. 25, 1905

PLUMB, HYLON THERON, Assistant Professor Alternating Currents, Purdue University, West Lafayette, Ind. June 19, 1903

PODLESAK, EMIL, President and Manager, N. J. Eng. & Const. Co., Morristown, N. J. Jan. 23, 1903

PODLESAK, HENRY JOSEPH, Consulting Mechanical and Electrical Engineer, 779 S. Ridgeway Ave., Chicago, Ill. Sept. 28, 1906

POIRIER, ALFRED E., N. Y. & N. J. Tel. Co., 15 Clinton St., Newark, N. J.; res., 11 East 47th St., New York City. May 21, 1901

POLLARD, NELSON LEVI, Electrical Engineer, Public Service Corporation; res. 114 Madison Ave., Elizabeth, N. J. Mar. 1, 1907

POMEROY, JAMES G., Western Manager, Adams Bagnall Electric Co., 309 Dearborn St., Chicago, Ill. Mar. 27, 1903

POMEROY, LEWIS ROBERTS, Special Representative Railway Dept., General Electric Co., 44 Broad St., New York City. Aug. 22, 1902

POMEROY, WILLIAM D., The Bullock Electric Mfg. Co., Cincinnati, Ohio. Mar. 22, 1899

PONTI, GIAN GIACOMO, Polytecnico, Turin, Italy. Aug. 17, 1904

POOLE, FREDERICK PARSONS, Electrical Engineer, Bryant Electric Co.; res., 1465 Fairfield Ave., Bridgeport, Conn. Oct. 27, 1905

POOLE, WILLIAM JOHN, Engineer and Salesman, British Westinghouse Electric and Mfg. Co. Ltd., Glasgow, Scotland. Mar. 29, 1907

POOLER, MAX ALPHONSE, Electrical Engineer, 145 Lincoln Ave., Youngstown, O. Feb. 24, 1905

POOR, FREDERIC HEDGE, Tester, General Electric Co.; res., 241 Liberty St., Schenectady, N. Y. Apr. 28, 1905

POPE, HARRY BONFIELD, Montreal Light, Heat and Power Co., Richelieu Village, Que. Mar. 27, 1903

POPE, HENRY WILLIAM, American Telephone & Telegraph Co., 15 Dey St., New York City; res., Stapleton, N. Y. Mar. 23, 1898

POPE, RALPH WAINWRIGHT, Secretary to the American Institute of Electrical Engineers, 33 W. 39th St., New York City. June 2, 1885

POPE, WILLIAM GODFREY THOMAS, La Union Telephonica, 1193 Rivadavia, Buenos Aires, A. R. Dec. 23, 1904

POPPLETON, RALPH RIGGS, Sales Engineer, Pacific Electric Co., 94 First St., Portland, Oregon. Mar. 29, 1907

PORTER, CHARLES HUNTINGTON, [*Local Secretary*], Dept. Electrical Engineering, Mass. Inst. Tech., Boston, Mass. Dec. 19, 1902

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PORTER, EDWARD YOUNGS, Electrical Engineer, Moore Electrical Co., Newark; res., 47 West St., E. Orange, N. J. June 14, 1905

PORTER, H. HOBART, JR., Sanderson & Porter, 52 William St., New York; City; res., Lawrence, L. I. Mar. 25, 1896

PORTER, JOHN WILLIAM, Partner, Porter & Berg, Chicago; res., 1351 Sheridan Road, Edgewater, Ill. Mar. 27, 1903

PORTER, LATTA WALDO, Secretary and Manager, Cincinnati Construction Co.; res., 320 W. 4th St., Cincinnati, O. Sept. 28, 1906

PORTER, ROYAL ARTHUR, [*Local Secretary*] Assistant Professor of Physics, Syracuse University, Syracuse, N. Y. Feb. 23, 1906

POST, ARTHUR WOOD, Student, Brooklyn Polytechnic Institute, Brooklyn; res., Westbury, L. I. N. Y. Dec. 28, 1906

POSTE, H. C. F., Electrical Superintendent Aluminum Co. of America, Massena, N. Y. Jan. 29, 1904

POSTEL, FRED J., Electrical Engineer, Postel & Linn, 705 Fisher Bldg.; res., 5227 Calumet Ave., Chicago, Ill. Nov. 24, 1905

POTT, ARTHUR HENRY, Chief Engineer, Metropolitan Electric Tramways, Ltd., London, Eng. Nov. 22, 1901

POTTER, ARVIN HENRY, Chief Installer, Tri-State Telephone and Telegraph Co.. Minneapolis, Minn. June 21, 1907

POTTER, CARROLL, Superintendent, Electric Storage Battery Co., 19th St. and Allegheny Ave., Philadelphia, Pa. Sept. 26, 1902

POTTER, HERBERT STURGIS, Electrical Engineer and Contractor, 24 Commercial St., Boston, Mass. May 17, 1904

POTTER, JOHN CHURCH, Instructor in Electrical Engineering, University of Wisconsin, Madison, Wis. Jan. 25, 1907

POTTS, LOUIS MAXWELL, Constructing Engineer, Rowland Telegraphic Co., 107 E. Lombard St., Baltimore, Md. Sept 6, 1902

POTTS, ALFRED GILBERT, Engineer, Union Railway Supply Co., 1633 Real Estate Trust Bldg., Philadelphia, Pa. Mar. 1, 1907

POWELL, CHARLES SKRINE, General Agent, Westinghouse Electric and Mfg. Co., 111 Broadway, New York City. June 14, 1905

POWELL, EDWIN BURNLEY, Stone and Webster, Engineering Corporation 147 Milk St., Boston, Mass. May 21, 1901

POWELL, IVAN ELNO, Engineer, Rochester Railway and Light Co., 120 Broadway, Rochester, N. Y. Mar. 29, 1907

POWELL, PERCIVAL HERBERT, Lecturer, Canterbury College, Christ-Church, N. Z. Dec. 28, 1906

POWELL, PERCY HOWARD, *M. E.*, 543 Washington Ave., Bridgeport, Conn. Sept. 25, 1895

POWELL, RICHARD CHEADLE, Draftsman, 2710 Haste St., Berkeley, Cal. Oct. 26, 1906

POWELSON, WILFRED VAN NEST, Union Electric Light and Power Co., St. Louis, Mo. Jan. 24, 1900

POYNTON, WILLIAM PERCIVAL, Western N. Y. Construction Co., 486 Ellicott Sq., Buffalo, N. Y. Mar. 25, 1904

PRATT, ALEXANDER, Supt. H. R. T. & L. Co.; res., Matlock Ave., rear Pukoi St., Honolulu, H. T. Jan. 23, 1903

PRATT, ARTHUR C., Electrician, Missouri River Pr. Co., Canyon Ferry, Mont. Jan. 23, 1903

PRATT, CHARLES RICHARDSON, Consulting Engineer, 1123 Broadway, New York City; res., Montclair, N. J. May 19, 1903

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PRATT, ELROY J., Electrical Engineer, Southwest Mo. Electric Railway Co., Webb City, Mo. Apr. 27, 1906

PRATT, GEORGE LEWIS, Vice-President, N. P. Pratt Laboratory, Atlanta, Ga. Oct. 26, 1906

PRATT, LOUIS WASHINGTON, [*Local Secretary*] Secretary, Federal Electric Construction Co., Ltd., Toronto, Ont. Sept. 22, 1905

PRATT, RICHARD HENRY, Chief Electrician, N. P. Pratt Laboratory, Atlanta, Ga. Mar. 29, 1907

PRESS, ABRAHAM, George Washington University, Faculty of Graduate Studies; res., 17th and T. Sts., Washington, D. C. June 21, 1907

PRESSEY, HENRY ALBERT, Civil Engineer, 408 Colorado Bldg., Washington, D. C. Dec. 23, 1904

PRICE, CHAS. W., Editor, the *Electrical Review*, 13 Park Row, New York, City; res., 223 Garfield Pl., Brooklyn, N. Y. Sept. 19, 1894

PRICE, ALDEN SHERMAN, Student Brooklyn Polytechnic Institute, Brooklyn; res., 318 W. 101st St., New York City. Sept. 28, 1906

PRICE, EDGAR F., Works Manager, Union Carbide Co., 157 Michigan Ave., Chicago, Ill. June 27, 1895

PRICE, HAROLD WILBERFORCE, Lecturer, in Electrical Engineering, School of Science, Toronto, Ont. Dec. 18, 1903

PRICE, JAMES A., Inspector Electrical Locomotives, N. Y. C. R. R. Co., American Locomotive Works, Schenectady, N. Y. Apr. 23, 1903

PRICE, JOHN BELVIN, Superintendent, Richmond Electric Co., Richmond, Va. Sept. 28, 1906

PRICE, NORMAN I., Australian General Electric Co., Melbourne, Aus. Feb. 28, 1902

PRICE, WILLIAM MONTELIUS, Seattle Electric Co., Seattle, Wash. Mar. 25, 1904

PRINCE, FREDERICK WELLES, Superintendent of Construction, Hartford Electric Light Co.; res., 821 Broad St., Hartford, Ct. Oct. 23, 1903

PRINCE, J. LLOYD, The New York Edison Co., New York City; res., 868 Flatbush Ave. (Flatbush Station), Brooklyn, N. Y. Feb. 27, 1895

PRINDLE, EDWIN J., Patent Lawyer, Prindle and Williamson, 220 Broadway, New York City. Apr. 27, 1906

PROCTOR, THOS. L., Marine Electrical Equipment, 149 Broadway, New York City; res., Elmhurst, L. I., N. Y. Apr. 18, 1894

PROSSER, HERMAN A., Dooley Block, Salt Lake City, Utah. Jan. 26, 1898

PROTZELLER, HARRY W., Construction Department, General Electric Co., Schenectady, N. Y. Nov. 23, 1906

PRUESSMAN, OTTO, Telephone Engineer, Western Electric Co.; res., 1621 Aldine Ave., Chicago, Ill. June 21, 1907

PROUD, OWEN E., Electrician, Pennsylvania R.R. Co., 1518 Filbert St.; res., 1153 N. 62d St., Philadelphia, Pa. Dec. 28, 1906

PRYCE, EDMUND HUGH, 133 Warburton Ave., Yonkers, N. Y. Feb. 26, 1904

PUDAN, HERBERT WHATMOUGH, Consulting Electrical Engineer, 452 Moreno, Buenos Aires, A. R. Sept. 25, 1903

PUNGA, FRANKLIN, Electrical Engineer, 87 Gundeldinger Strasse, Bale Switzerland. Jan. 29, 1904

PUPIN, MICHAEL, I., Adjunct Professor in Mechanics, Columbia University; res., 280 North Broadway, Yonkers, N. Y. Mar. 18, 1890

PUTNAM, HARRY AMES, Cable Tester, J. A. Roebling's Sons Co.; res., 138 E. Hanover St., Trenton, N. J. May 15, 1905

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PUTNAM, JOSEPH EDWARD, Assistant on Electrolysis, Engineering Bureau of the City of Rochester, City Hall, Rochester, N. Y. Mar. 27, 1903

PUTNAM, JOSEPH WARREN, Assistant Engineer, Toronto and Niagara Power Co.; res., 758 King St. East, Hamilton, Ont. Apr. 26, 1907

PUTT, HARVEY J., Chief Electrical Operator, Manhattan Railway Co., 74th St. and East River, New York City. Mar. 27, 1903

QUEENY, JOHN T., Salesman, Westinghouse Electric and Mfg. Co., 716 Board of Trade Bldg., Boston, Mass. Mar. 24, 1905

QUIGLEY, ARTHUR J., Assistant to Supt. of Construction, J. G. White & Co., Rock Island, Ill. Nov. 25, 1904

QUINAN, GEORGE ELY, Asst. Supt., Power. Tacoma Railway & Power Co.; res., 410 So. C. St., Tacoma, Wash. Aug. 17, 1904

QUINN, CHARLES J., JR., Engineer, res., 161 Kosciusko St., Brooklyn, N. Y. Aug. 17, 1904

RADLEY, GUY RICHARDSON, Designing Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis. Sept. 25, 1903

RALSTON, ALBERT LENNERT, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 1, 1907

RALSTON, JOSEPH H., Contracting Engineer; res., 506 E. Third St., Albany, Ore. April 26, 1907

RAMSEY, ALLAN, Union Electric Light and Power Co., 10th and St. Charles St., St. Louis, Mo. June 21, 1907

RAMSEY, JAMES C., JR., Electrical Engineer, The American Woolen Co.; res., Lawrence, Mass. Apr. 23, 1903

RANDALL, JOEL ELMER, Student, Brooklyn Polytechnic Institute; res., 313 Sixth Ave., Brooklyn, N. Y. Jan. 25, 1907

RANDALL, JOHN E., Cleveland Lamp Factory, cor. Mason & Beldon Sts., Cleveland, Ohio. May 7, 1889

RANDALL, KARL CHANDLER, Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

RANDOLPH, MERVYN PAUL, District Office Manager, Westinghouse E. & M. Co., 314 Occidental Ave., Seattle, Wash. Jan. 24, 1902

RANKIN, ROBERT, Electrical Engineer, Sao Paulo Tramway Light and Power Co., Sao Paulo Brazil. June 21, 1907

RANKINE, DE LANCY, Niagara Falls Power Co., Niagara Falls, N. Y. Mar. 27, 1903

RANNEY, AMBROSE ELLIOTT, Engineer, Elmore Automobile Co., 1851 Broadway, New York City. June 21, 1907

RANNEY, EARL EUGENE, Testing Department, Electric Controller & Supply Co., Cleveland, Ohio. June 21, 1907

RANSOM, ALLEN EDWARD, Westinghouse Electric & Mfg. Co., 314 Occidental Ave., Seattle, Wash. Jan. 3, 1902

RAPELJE, CHARLES VANDERVEER, Superintendent, Traction Equipment Co., 72 Grand Ave., Brooklyn, N. Y. June 21, 1907

RAPELJE, P. DITMARS, Engineer of Services, New York Edison Co., New York City; res., 948 Belmont Ave., Brooklyn, N. Y. June 21, 1907

RASMASON, H. LEWIS, Superintendent of Construction, Telluride Power Co., Grace, Idaho. Aug. 25, 1905

RASK, LOUIS, Electrical Engineer, General Electric Co.; res., 204 Union St., Schenectady, N. Y. Sept. 28, 1906

RATTERMANN, C. J., Salesman, Allis-Chalmers Co.; res., 2419 Ohio Ave., Cincinnati, O. Feb. 23, 1906

RAUCH, WILLIAM GEORGE, with Allen J. Krebs, 1008 So. 20th St., Birmingham, Ala. Oct. 26 1906

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RAWSON, HOBART, Electrical Engineer, Electrical Dept, Long Island R. R., Long Island City, N. Y. June 15, 1904

RAY, FREDERICK LUCIEN, Superintendent of Construction, W. M. Sheehan & Co., 136 Liberty St., New York City. Sept. 28, 1906

RAY, LAWRENCE W., Central District & Printing Telegraph Co., Pittsburg, Pa. Mar. 24, 1905

RAY, WEBSTER WAGNER, General Electric Co.; 1047 Monadnock Building, Chicago, Ill. Oct. 27, 1905

RAYMOND, EDWARD BRACKETT, Electrical Engineer, General Electric Co., Schenectady, N. Y. May 20, 1902

RAYMOND, FRANCIS, III., 1635 Old Colony Bldg., Chicago, Ill. Oct. 28, 1904

RAYMOND, HOWARD MONROE, Dean, Professor Experimental Physics, Armour Institute of Technology, Chicago, Ill. Mar. 29, 1907

REA, NORMAN LESLIE, Construction Department, General Electric Co.; res., 107 Lafayette St., Schenectady, N, Y. Aug. 22, 1902

READ, HOMER WEST, Installer, Sunset Telephone & Telegraph Co.; res., 5565 Kenwood Place, Seattle, Wash. Sept. 28, 1906

READ, JOHN ROYALL, Electrical Engineer, Canadian Westinghouse Co., Ltd., 152 Hastings St., Vancouver, B. C. Feb. 26, 1904

READ, ROBERT H., Patent Attorney, General Electric Co., Schnectady, N. Y. Jan. 19, 1892

READ, WALTER VAN HOUTEN, Transmission Inspector, Central District and Printing Telegraph Co., Pittsburg, Pa. Mar. 1, 1907

REDDING, SAMUEL ARTHUR, Electrical Engineer, Georgia Railway & Electric Co., 562 N. Boulevard, Atlanta, Ga. Mar. 25, 1904

REDSHAW, WILLIAM ARTHUR, Electrical Engineer, Public Service Corporation of N. J.; res., New Brunswick, N. J. June 21, 1907

REED, CHAS. J., Electrician, 3313 N. 16th St., Philadelphia, Pa. Mar. 5, 1889

REED, FREDERICK HOLLY, Vice-president, J. G. White & Co., 43 Exchange Pl.; res., 265 W. 81st. St., New York City. Apr. 22, 1904

REED, HARRY D., Superintendent Bishop Gutta Percha Co., 420 East 25th St., New York City; res., Newark, N. J. Sept. 19, 1894

REED, HENRY A., Secretary and Manager, Bishop Gutta-Percha Co., 422 East 25th St., New York City; res., Newark, N. J. June 4, 1899

REED, LEANDER NELSON, Sales Engineer, Westinghouse Electric and Mfg. Co., Boston; res., 102 Belmont St., Somerville, Mass. Jan. 25, 1907

REED, LYMAN COLEMAN, Spranley & Reed, 919 Hibernian Bank Building, New Orleans, La. Mar, 25, 1904

REED, ROBERT CARTER, Superintendent of Electrical Department, Carnegie Steel Co., Duquesne, Pa. Apr. 23, 1903

REED, WARREN BETTISON, Consulting Engineer, 1011 Hibernia Bank Bldg., New Orleans, La. June 14, 1905

REGESTEIN, ERNEST ALBRECHT, Standard Underground Cable Co., 619 Westinghouse Bldg., Pittsburg. Pa. May 19, 1903

REGESTER, CHARLES W., Westinghouse Electric and Mfg. Co., 1220 New York Life Bldg., Chicago, Ill. Dec. 19, 1902

REHFELD, GROVER GEORGE, Electrician, 1433 Prairie St., Milwaukee, Wis. Apr. 27, 1906

REICH, WILLIAM I., Consulting Engineer, 407 Fourth Ave., Pittsburg, Pa. May, 19 1903

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REICHENBACH, FREDERIC, Electrical Assistant, Signal Service, U. S. Army Washington, D. C. May 19, 1903

REID, CLARENCE ERLE, Assistant Professor of Electrical Engineering, Case School of Applied Sciences, Cleveland, O. May 19, 1903

REID, EDWIN S., General Supt. and Engineering, National Conduit and Cable Co., Oxford Court, Cannon St., London, Eng. Feb. 26, 1896

REID, EUGENE J., Draughtsman, New York Edison Co.; res., 1200 Franklin Ave., New York City. May 15, 1905

REID, GEORGE HAROLD, Electrical Engineer, General Electric Co., Schenectady, N. Y. May 14, 1906

REID, HARRY PALMER, Sales Engineer, Emerson Electric Mfg. Co., St. Louis, Mo. Feb. 26, 1904

REID, THOMAS BATCHELOR, 59 Early St., Morristown, N. J. Apr. 28, 1905

REID, WALTER DAVID, Telephone Engineer, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass Mar. 1, 1907

REILLY, HARRY WINNE, J. G. White & Co., 43 Exchange Place, New York City. Jan. 3, 1902

REILLY, JOHN C., General Supt., N. Y. & N. J. Tel. Co., 81 Willoughby St., Brooklyn, N. Y. Apr. 15, 1884

REILLY, JOHN JOSEPH, Assistant Foreman, Meter Department, Philadelphia Electric Co., 122 Arch St., Philadelphia, Pa. Apr. 26, 1907

REIMERS, FREDERICK WILLIAM, Electrical Engineer, J. G. White and Co., 1136, 2d Ave., Rock Island, Ill. Apr. 26, 1907

REMINGTON, GEORGE WARD, Engineer Railway Department, General Electric Co., Schenectady, N. Y. Mar. 29, 1907

REMSCHEL, CESAR WILHELM AUGUST, Electrical Engineer, Allis-Chalmers Co., Seattle, Wash. Feb. 28, 1902

RENNARD, JOHN CLIFFORD, *A.B.*, *E.E.*, Asst. Chief Engineer, New York Telephone Co., 15 Dey St., New York City. Jan. 16, 1895

RENSHAW, CLARENCE, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Aug. 22, 1902

RENSTROM, FRANS OSCAR, Consulting Electrical Engineer, Skelleftea, Sweden. Feb. 28, 1900

RENSTRÖM, JONAS ALFRED, Superintendent, Regla Power Transmission, Pachuca, Mexico. Nov. 25, 1904

REPLOGLE, JAMES GILLESPIE BLAINE, Assistant Electrical Inspector, Western Electric Co., Chicago, Ill. Oct. 24, 1902

RETALLIC, CHARLES, Superintendent, The Light and Power Commission, Marquette, Mich. Aug. 25, 1905

REUTLINGER, CHARLES, Construction Engineer, Chesapeake and Potomac Telephone Co., 5 Light St., Baltimore, Md. Apr. 28, 1905

REW, FRANK ALBERT, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Sept. 28, 1906

REYNDERS, ARTHUR BERNARD, General Engineer Insulation Work, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. June 21, 1907

REYNOLDS, BAXTER, Fairbanks, Morse & Co., 12 Dey St., New York City. Feb. 23, 1906

REYNOLDS, EDWARD LANDSDALE, Manager of Pennsylvania Sales Office; The Electric Storage Battery Co., Philadelphia, Pa. May 19, 1903

REYNOLDS, HARRY F., Reynolds Electric Co. Inc.; Seattle, Wash. Mar. 27, 1903

REYNOLDS, H. H., Chief Electrical Engineer, Kilburn & Co., 4 Fairlie Place, Calcutta, British India. Oct. 28, 1904

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REYNOLDS, LOUIS EMBLEE, Superintendent of Distribution, San Francisco Gas and Electric Co., San Francisco, Cal. Mar. 28, 1902

REYNOLDS, WILLIAM HENRY, 288 Lenox Ave., New York City. Nov. 25, 1904

RHODES, C. BORIE, Manager, Willamette Valley Co., Tonopah, Nev. Jan. 25, 1907

RHODES, FREDERICK LELAND, Electrical Engineer, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Mar. 27, 1903

RHODES, GEORGE IRVING, Assistant Engineer, Interborough Rapid Transit Co., 59th St. and 11th Ave., New York City. Nov. 23, 1906

RHODES, HARRY ASP, Chief Engineer, The Colorado Telephone Co., 1421 Champa St., Denver, Colo. Mar. 27, 1903

RHODES, SAMUEL GLENN, Superintendent, Arc Lamp Department, New York Edison Co., 117 W. 39th St., New York City. Apr. 27, 1906

RIBOT, ANTONIO, Tester General Electric Co.; res., 131 Church St., Schenectady, N. Y. Mar. 29, 1907

RICE, ARTHUR, Engineer, The New York Telephone Co., 15 Dey St.; res., 453 W. 117th St., New York City. Mar. 27, 1903

RICE, ARTHUR LOUIS, Managing Editor, *The Engineer*, Publishing Co., 355 Dearborn St., Chicago, Ill. Oct. 21, 1896

RICE, HORACE ELMER, Philadelphia Electric Co.; res., 5841 Crittenden St., Germantown, Philadelphia, Pa. Aug. 25, 1905

RICE, MARTIN P., Chief of Publication Bureau, General Electric Co., Schenectady, N. Y. May 21, 1901

RICE, PHILIP BERNARD, Assistant in Office of Mechanical Engineer, Pennsylvania Railroad Co., Altoona, Pa. Mar. 29, 1907

RICE, RALPH HERBERT, Asst. Division Engineer, Bd. of Supervising Engineers, Chicago Traction, 181 La Salle St. Chicago, Ill. Jan. 29, 1904

RICE, WILLIAM JACKSON, Chief of Supplies, N. Y. & N. J. Telephone Co., 160 Market St.; res., 43 South St., Newark, N. J. Nov. 24, 1905

RICH, EDWARD BENJAMIN, Field Accountant on Coast Analysis, Northwestern Cnstruction Co., Boone, Ia. Mar. 29, 1907

RICH, FRANCIS ARTHUR, Manager, Woodstock G. M. Co., Karangahake, Auckland, New Zealand. Jan. 20, 1897

RICH, SIDNEY LEONARD, Purchasing Agent, B-R. Electric Co.; res., 330 So. Pryor St., Atlanta, Ga. Feb. 26, 1904

RICHARDS, EDGAR ULYSSES, Electrical Inspector, Ohio Inspection Bureau, Columbus, O. Feb. 23, 1906

RICHARDS, EDWARD, Assistant Engineer, Hydro-Electric Power Commission, 25 Toronto St., Toronto, Ont. Aug. 25, 1905

RICHARDS, WALTER JOSEPH, Chief Engineer, National Brake & Electric Co., Milwaukee, Wis. Jan. 25, 1907

RICHARDS, WILLIAM EDGAR, General Line Foreman, Toledo Railways and Light Co., Toledo, Ohio. Aug. 17, 1904

RICHARDSON, JOHN BELDEN, Construction Foreman, Westinghouse Electric and Mfg. Co., 120 Liberty St., New York City. Feb. 24, 1905

RICHARDSON, JOSEPH W. A., Contractor, 715 Union St., New Orleans, La. Apr. 22, 1904

RICHARDSON, STUART, Electrical Engineer, Wellington City Corporation, 117 Brougham St., Wellington, N. Z. Jan. 26, 1906

RICHARDSON, THOMAS SMITH, Electrical Engineer, Auburn Light, Heat & Power Co.; res., 73 South St., Auburn, N. Y. Mar. 27, 1903

RICHMOND, JOHN STANLEY, Consulting Engineering Expert, 32 Adelaide St. East, Toronto, Ont. Jan. 26, 1906

RICHTBURG, HERMANN ANDREAS, Electrical Engineer, Western Electric Co., 463 West St., New York City. Sept. 27, 1901

RICKENBACHER, ALBERT DOMINICK, Electrician, J. G. White and Co.; res., 1213 G. St. N. W., Washington, D. C. June 21, 1907

RICKER, CHARLES W., Electrical Engineer, Cleveland Construction Co., 606 Citizen's Building, Cleveland, Ohio. Jan. 29, 1904

RIDDILE, JOHN SCOTT, ENGINEER, with Ralph D. Mershon, 60 Wall St.; res., 102 W. 84th St., New York City. Mar. 29, 1907

RIDEOUT, ALEXANDER C., *LL.D.*, Consulting Elec. and Mech. Engineer, Rideout & Gage, 101 Randolph St., Chicago, Ill. Aug. 5, 1896

RIGNEY, FLEMING JAMES, Electrical Engineer, Kirby Lumber Co., Bessmay, Texas. Sept. 28, 1906

RIKO, YASUO, Electrical Engineer, Department of Communications, Tokio, Japan. Oct. 23, 1903

RILEY, CHAMPLAIN LORD, Consulting Engineer, Clark and MacMullen, 20 Broad St., New York City. Mar. 1, 1907

RIONDA, MANUEL ENRIGNE, Partner and Director, Czarnikow MacDonald & Co., 112 Wall St., New York City. Apr. 26, 1907

RIPLEY, CHARLES MEIGS, Electrical Engineer, Gould Storage Battery Co., 341 Fifth Ave., New York City. July 28, 1905

RIPLEY, LEROY ORMAND, Manager, Schenectady Illuminating Co., Schenectady, N. Y. Oct. 27, 1905

RIPPEY, S. HOWARD, Consulting Engineer, 1301 Stephen Girard Building, Philadelphia, Pa. Jan. 29, 1904

RIPPLE, PAUL W., Electrical Engineer, New England Investment & Security Co., Room 536 South Station, Boston, Mass. Oct. 28, 1904

RISELEY, HARRY LORIMER, Resident Engineer, Newcastle Electric Supply Co., Wallsend, Eng. Jan. 29, 1904

RITCHIE, THOMAS EDWARD, Business Manager, Royce, Ltd.; res., 179 Barton Rd., Stretford, Manchester, Eng. May 20, 1902

RITCHIE, WILLIAM TRAILL, National Mortgage Agency Co., 8 Great Winchester St., London E. C., England Nov. 24, 1905

RITSCHY, LEWIS JOHN, 3424 Hartford St., St. Louis, Mo. Dec. 18, 1903

RITTENHOUSE, WALTER B., Mechanical Engineer, Great Northen Power Co., 315 Providence Building, Duluth, Minn. Sept. 25, 1903

RIVET, ANTOINE RUSH, Financial and Commercial Editor, *Globe-Democrat*; res., 7511 Pennsylvania Ave., St. Louis, Mo. May 19, 1903

ROBB, GEORGE C., Sacramento River Supply Co., Sacramento, Cal. Jan. 23, 1903

ROBBINS, CHARLES, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Apr. 23, 1903

ROBBINS, PERCY ARTHUR, Consulting Engineer, 60 Wall St., New York City. June 19, 1903

ROBERSON, OLIVER R., Electrician, Lambertville, N. J. Dec. 20, 1893

ROBERTS, ALLEN DAVIDSON, Electrician, 12½ King St., Kingston, Jamaica, West Indies. Nov. 22, 1899

ROBERTS, DAVID ALLEN, Partner, Philadelphia Electric Construction Co., 914 Filbert St., Philadelphia, Pa. July 26, 1907

ROBERTS, OSWALD MORTIMER, Superintendent, Orangeburg Electric Light and Water Plant, Orangeburg, S. C. June 21, 1907

ROBERTS, THOMAS MAYO, Mechanical Draughtsman and Electrical Engineer, Gen. Elec. Co., 84 State St., Boston, Mass. Dec. 19, 1902

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ROBERTS, WILLIAM, Superintendent Motive Power, Northern Ohio Traction and Light Co., Akron, Ohio. June 21, 1907

ROBERTSON, CHARLES EMERY, Robertson Electric Co., 15 to 21 Terrace, Buffalo, N. Y. Nov. 25, 1904

ROBERTSON, JAS. MCCALLUM, Superintendent, Power Department, Montreal Light, Heat and Power Co., Montreal, P. Q. Apr. 26, 1901

ROBERTSON, JAMES TOWNES, Electrician, South Eastern Tariff Association, Abbeville, S. C. May 14, 1906

ROBERTSON, WILLIAM LEROY, Philadelphia Electric Co., Philadelphia; res., 1006 Main St., Darby, Pa. July 28, 1905

ROBINSON, ALMON, Webster Road, Lewiston, Maine. Sept. 6, 1887

ROBINSON, CHARLES CLARK, Assistant, Engineering Department, Telluride Power Co., Provo, Utah. Aug. 25, 1905

ROBINSON, EDWIN GARDNER, JR., Jim Creek Water, Light and Power Co., Inc., Arlington, Wash. July 19, 1904

ROBINSON, FRANCIS GEORGE, New York Railway Co.; res., 605 W. 115th St., New York City. Nov. 21, 1894

ROBINSON, GEO. P., Pacific States Telephone and Telegraph Co., Scott and Fell Sts., San Francisco. May 16, 1899

ROBINSON, JOHN KNOWLTON, Agent, West Coast of South America, Westinghouse Elec. and Mfg. Co., Iquique, Chili, S. A. Sept. 26, 1902

ROBINSON, LAFOREST GEORGE, Electrical Engineer, Niagara Falls, Ont. Feb. 27, 1903

ROBINSON, LEWIS TAYLOR, Engineer, General Electric Co., Schenectady, N. Y. Aug. 17, 1904

ROBINSON, PAUL, Division Superintendent, California Gas and Electric Corporation; res., 2520 Hillegas Ave., Berkeley, Cal. Mar. 1, 1907

ROBINSON, PERCY GILMOUR, Wire Chief, Merriam Park Exchange, Tri-State Telephone and Telegraph Co., St. Paul, Minn. June 21, 1907

ROBINSON, RALPH HARPER, Storage Battery Engineer, San Francisco Gas and Electric Co., San Francisco, Cal. Feb. 23, 1906

ROBINSON, WALTER PILSBURY, Electrical Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 23, 1906

ROCHE, PERCY, 265 Shady Ave., Pittsburg, Pa. Mar. 27, 1903

ROCKWOOD, DWIGHT CARRINGTON, Rochester Railway & Light Co., Rochester, N. Y. Mar. 22, 1901

RODDEWIG, GEORGE WASHINGTON, Columbia University; res., 69 W. 93d St., New York City. Sept. 28, 1906

RODDEY, JOHN HARVEY, Assistant Engineering Department, Southern Power Co., Charlotte, N. C. Dec. 28, 1906

RODENBAECK, GEORGE ALBRECHT, Assistant, Massachusetts Institute of Technology, Boston, Mass. Apr. 26, 1907

RODGERS, ASHMEAD GRAY, Assistant Superintendent, The Carborundum Co., Niagara Falls, N. Y. Sept. 27, 1901

RODGERS, GEORGE BRANNER, Consulting Engineer, Assistant, Charles H. Ledlie, 918 Rialto Bldg., St. Louis, Mo. Oct. 26, 1906

RODMAN, WALTER SHELDON, Instructor in Physics and Electrical Engineering, Rhode Island College, Kingston, R. I. Mar. 1, 1907

ROE, JULIAN, Manager, Crocker Wheeler Co.; res., 4547 Michigan Ave., Chicago, Ill. Sept. 28, 1906

ROEBLING, FERDINAND W., Manufacturer of Electrical Wires and Cables, Trenton, N. J. June 8, 1887

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ROEDING, HENRY ULRICH, Secretary, Pierson Roeding & Co., 77 New Montgomery St., San Francisco, Cal. Sept. 25, 1903

ROFF, OTHO CLARENCE, Tester, General Electric Co.; res., 146 Nott Terrace, Schenectady, N. Y. Mar. 29, 1907

ROFFEY, MYLES HERBERT, Assistant, British Westinghouse Electric and Mfg. Co.; res., Littlecot, Hornchurch, Essex, Eng. Jan. 25, 1907

ROGERS, FRED A., Assistant Professor of Electrical Engineering and Physics, Lewis Institute, Chicago, Ill. Feb, 23, 1906

ROGERS, HARRY BELL, Salesman, Erner-Hopkins Co., 162 North 3d St., Columbus, O. Feb. 24, 1905

ROGERS, JOHN JAMES ROBERT CHARLES, Electrical Engineer, Lighting Station, Yaralla Concord, Sydney, N. S. W. May 19, 1903

ROGERS, NELSON W., Electrician, Cooper-Hewitt Laboratory, Madison Square Garden Tower, New York City. May 21, 1901

ROLF, ARTHUR F., Sales Engineer, Bullock Electric Mfg. Co., 71 Broadway, New York City. Feb. 27, 1903

ROMAN, JOSEPH MARTIN, 202 W. 137th St., New York City. Mar. 24, 1905

ROOKE, THOMAS, Resident Engineer, Messrs, Preece & Cardew, Town Hall, Sydney, N. S. Wales. Jan. 23, 1903

ROPER, DENNEY W., Electrical Engineer, Chicago Edison Co., 139 Adams St., Chicago. Ill. June 6, 1893

RORTY, MALCOLM CHURCHILL, Superintendent of Traffic, Central District & Printing Telegraph Co., Pittsburg, Pa. Mar. 27, 1903

ROSE, GEORGE STANTON, General Electric Co.; res., 841 Union St., Schenectady, N. Y. Dec. 28, 1906

ROSE, SIDNEY LEON ELLIOTT, Testing Department, General Electric Co.; res., 509 Summer St., West Lynn, Mass. Feb. 24, 1905

ROSEBRUGH, THOMAS REEVE, Professor of Electrical Engineering, University of Toronto, Toronto, Ont. June 26, 1891

ROSENBAUM, WM. A., Attorney in Patent Cases, Nassau-Beekman Building, 140 Nassau St., New York City. Jan. 3, 1889

ROSENBERG, E. M., *M. E.*, 6 W. 90th St., New York City. Oct. 21, 1890

ROSENBLATT, GIRARD B., Electrical Engineer, Westinghouse Electric and Mfg. Co., Butte, Mont. Mar. 27, 1903

ROSENQUEST, EUGENE H., President and General Manager, the Bronx, Gas and Electric Co., Westchester, N. Y. Mar. 27, 1903

ROSENSTENGEL, RUDOLPH, Instructor in Electrical Engineering, Agricultural and Mechanical College, Stillwater, Okla. Dec. 15, 1905

ROSENTHAL, LEON WALTER, Electrical Engineer, Columbia University; res., 240 West 137th St., New York City. Aug. 22, 1902

ROSS, JOHN OLIVER GORDON, Engineer, Otis Elevator Co.; res., 4 Glenwood Terrace, Yonkers, N. Y. Jan. 25, 1907

ROSS, TAYLOR WILLIAM, Newport News Shipbuilding and Dry Dock Co., res., 3114 West Ave., Newport News, Va. Mar. 25, 1896

ROSSMAN, JAMES G., 25 Broad St., New York City. Sept. 25, 1903

ROTH, RODOLFO, Engineer, traveler, Victor M. Braschi; res., Cadena St., No. 2, Mexico City, Mex. June 21, 1907

ROUGH, GEORGE CRUIKSHANK, Manager Sales Department, The Packard Electric Co., Ltd., St. Catharines, P. Q. Apr. 23, 1903

ROWE, GEORGE CLARENCE, Electrical Engineer, Agency, A. E. G., 67 Oreilly, Havana, Cuba. Feb, 27, 1903

ROWLAND, ARTHUR JOHN, Professor of Electrical Engineering, Drexel Institute; res., 4510 Osage Ave., Philadelphia, Pa. Sept. 19, 1894

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ROWLAND, HERBERT RAYMOND, Electrical Draftsman and Engineer, 1314 Continental Building, Baltimore, Md. Sept. 26, 1902

ROWNTREE, BERNARD, Burdette-Rowntree Mfg., Co., 147 W. 26th St., New York City. May 15, 1905

ROWNTREE, HAROLD, Secretary, Burdett-Rowntree Mfg. Co., 85 W. Jackson St.; res., 7321 Princeton Ave., Chicago, Ill. Apr. 26, 1907

RUCKER, BENJAMIN PARKS, Electrical Engineer, Westinghouse E. & M. Co., Pittsburg, Pa. July 28, 1903

RUCKGABER, ALBERT FELIX, with L. B. Stillwell, 100 Broadway, New York City. Nov. 22, 1901

RUEBEL, ERNST, Engineer, Ruebel Schwettmann Wells, 301 Chemica Building; res., 4649 Cottage Ave., St. Louis, Mo. Apr. 23, 1903

RUFFNER, CHARLES SHUMWAY, Electrician, The Telluride Power Co., Provo, Utah. Feb. 28, 1902

RUGG, HOWARD VAN, District Engineer, Westinghouse Electric and Mfg. Co., 2011 Market St., Philadelphia, Pa. July 26, 1907

RUGG, WALTER S., Engineer, Westinghouse Elec. & Mfg. Co., 11 Pine St.; res., 225 W. 83d St., New York City. Mar. 28, 1902

RUGGLES, W. ARTHUR, Board of Education, 9th and Locust Sts., St. Louis, Mo. Apr. 28, 1905

RUPE, EDWIN HERVEY, Telephone Engineer, Kellogg Switchboard and Supply Co., 1456 Leland Ave., Chicago, Ill. Apr. 26, 1907

RUSH, FLETCHER GRAY, Special Agent, Hartford Fire Insurance Co., 719 Equitable Building, Atlanta, Ga. Dec. 28, 1906

RUSH, HARRY SPEER, Inspection Department, North Shore Electric Co.; res., 835 Michigan Ave., Evanston, Ill. Apr. 26, 1907

RUSHMORE, SAMUEL W., Proprietor, Rushmore Dynamo Works, 629 South Ave., Plainfield, N. J. Mar. 28, 1903

RUSSEL, EDGAR, Major, Chief Signal Office, Washington, D. C. Nov. 22, 1901

RUSSELL, CHARLES J., District Manager, Philadelphia Electric Co.; res., 3422 Disston St., Tacony, Philadelphia, Pa. Nov. 25, 1904

RUSSELL, FRANK HENRY, President Automatic Hook and Eye Co., Hoboken; res., 131 Sylvan St., Rutherford, N. J. Jan. 25, 1907

RUSSELL, GEORGE WILLIAM, JR., Electrical Engineer and Contractor, Russell & Co., 500 5th Ave., New York City. Jan. 23, 1903

RUSSELL, H. A., Sales Agent, General Electric Co., res., 302 Laurel St., San Francisco, Cal. Nov. 22, 1899

RUSSELL, JAMES MILLAR, Student Polytechnic Institute; res., 881 East 15th St., Brooklyn, N. Y. Feb. 23, 1906

RUSSELL, LEONARD POMEROY, Curtis & Hine, Giddings Bldg., Colorado Springs, Colo. June 21, 1907

RUSSELL, SAMUEL, JR., Manager Crocker-Wheeler Co., 1315 North American Bldg., Philadelphia, Pa. Jan. 25, 1907

RUST, HAROLD NORWOOD, Shepherd & Rust, Wilkes-barre, Pa. Sept. 28, 1906

RUTH, EDWARD DILLER, Superintendent, Lancaster Electric Light, Heat and Power Co., Lancaster, Pa. Apr. 27, 1906

RUTHERFOORD, BRABAZON, Consulting Engineer, Westinghouse Building; res., 6327 Howe St., Pittsburg, Pa. July 25, 1902

RUTHERFORD, JAMES, Switchboard Regulator, New York Edison Co., 117 W. 39th St., New York City. Oct. 27, 1905

RYAN, WALTER D'ARCY, Engineer, General Electric Co., Lynn, Mass. Jan. 24, 1902

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RYAN, WILLIAM CHARLES MELBOURNE, Electrical Engineer, Simmen Automatic Railway Signal Co., Oakland, Cal. Sept. 28, 1906

RYAN, WILLIAM THOMAS, Instructor in Electrical Engineering, University of Minnesota, Minneapolis, Minn. Mar. 29, 1907

RYDER, BENJAMIN HUDSON, Sales Agent, American Steel and Wire Co., 826 Frick Building, Pittsburg, Pa. Apr. 27, 1906

RYDER, M. P., Supt. of Bronx Dist., New York Edison Co., 140th St. and Rider Ave., New York City. May 21, 1901

RYERSON, WM. NEWTON, Superintendent, Ontario Power Co., Niagara Falls, Ontario. Aug. 23, 1899

RYPINSKI, MAURICE CHARLES, 4924 Center Ave., Pittsburg, Pa. Mar. 27, 1903

SACCAGGIO, PIETRO CELESTINO, Leading Draftsman, Estacion Tallero (F. C. Sud), Dept. Locomotora, Buenos Aires, A. R. June 19, 1903

SADLER, DEHOPE, Operator, Rock Hill, S. C. June 21, 1907

SAGE, DARROW, Superintent of building, Room 1103 Park Row Building, New York City. Sept. 27, 1901

SAGE, FREDERICK BRITTAIN Room 1302 Havemeyer Building, New York City. May 21, 1901

SAGER, FRED ANSON, Engineer, The Arnold Co., 181 La Salle St.; res., 5116 East End Ave., Chicago, Ill. Nov. 24, 1905

SAGER, LAWRENCE KINGSLEY, Patent Lawyer and Electrical Expert 2 Rector St., New York City. June 21, 1907

SAHULKA, DR. JOHANN, Docent of Electrotechnics, Technische Hochschule Vienna, Austria. Dec. 20, 1893

SAKAI, YASUDIRO, Engineering Department, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. June 21, 1907

SALOMON, ARTHUR F., Manager, World's Fair Office, Nernst Lamp Co.; res., 4512 Cook Ave., St. Louis, Mo. Apr. 22, 1904

SAMMETT, MATTHEW ALEXANDER, In charge Testing Department, Montreal Light, Heat and Power Co., Montreal, P. Q. Mar. 27, 1903

SAMPSON, GEORGE HENRY, JR., Electrical Engineer, 595 Madison St., Portland, Ore. Dec. 19, 1902

SAMUELS, MAURICE M., Engineer, General Electric Co., Schenectady, N. Y. Mar. 29, 1907

SANDBORGH, OLOF ALFRED, Designing Engineer, Westinghouse E. & M. Co., Pittsburg, Pa. Mar. 27, 1903

SANBORN, ARTHUR ROSCOE, Expert Electrical Aid, William Cramp and Sons, Philadelphia, Pa. Dec. 28, 1906

SANDELL, SIXTEN OTTO, Draftsman, New York Edison Co., New York City. Feb. 24, 1905

SANDER, GEORGE HERMANN, Engineer, General Electric Co.; res., 20 S. Wendell Ave., Schenectady, N. Y. May 14, 1906

SANDERSON, CLARENCE HERBERT, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 1, 1907

SANDERSON, EDWIN N., Sanderson & Porter, Engineers and Contractors 52 William St., New York City. Oct. 17, 1894

SANDS, HERBERT STEAD, Engineering Salesman, Westinghouse Electric and Mfg. Co.; 429 17th St., Denver, Colo. May 14, 1906

SANFORD, EARL L., Construction Engineer, Canadian Westinghouse Co., Ltd., Niagara Falls Center, Ont. Apr. 23, 1903

SANFORD, GEORGE EDWIN, Electrician, General Electric Co.; res., 20 Holton Place, W., Lynn, Mass. Apr. 23, 1903

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SANFORD, WARREN BIXBY, Designing Engineer, United Telpherage Co., 20 Broad St., New York City. Nov. 25, 1904

SANGSTER, JOSHUA, Power House Supt., Hamilton Electric Light and Cataract Power Co., Power Glen, Ont. Jan. 23, 1903

SANVILLE, HENRY F., [*Local Secretary*], Dodge & Day, 597 Drexel Bldg., Philadelphia, Pa. Feb. 28, 1901

SARGENT, HOWARD R., Engineer of Wiring Supplies, General Electric Co.; res., 2 Rugby Road, Schenectady, N. Y. Mar. 25, 1896

SATHERBERG, CARL HUGO, Chief Engineer, The Midvale Steel Co., Nicetown, Philadelphia, Pa. Aug. 5, 1896

SAVAGE, HENRY., Electrician, 13 Bloomfield St., London Wall, London, Eng. Jan. 29, 1904

SAWIN, GEORGE ALFRED, Assistant Engineer, Meter Department, General Electric Co., Lynn, Mass. Apr. 23, 1903

SAWYER, BURTON MANSFIELD, 1137 West 1st St., Los Angeles, Cal. Nov. 20, 1903

SAWYER, WILLETS HERBERT, Engineer, Ford, Bacon & Davis, 24 Broad St., New York City. Feb. 28, 1902

SAXELBY, FREDERICK, Electrical Engineer, 39 Cortlandt St., New York City; res., East Orange, N. J. June 5, 1888

SAYER, EUGENE YOUNG, Vice President and General Manager, Improved Equipment Co., 60 Wall St., New York City. June 21, 1907

SAYLES, HENRY WHITMAN, Manager, Electrical Testing Co., 922 S. Adams St., Peoria, Ill. Mar. 24, 1905

SAYLOR, FREDERICK ALEXANDER, Master Mechanic, N. Y. & L. I. Traction [Life Member.] Co., Hempstead, L. I. Jan. 24, 1900

SCALES, HENRY JACKSON, Electrical Department, American Sheet and Tin Plate Co., Vandergrift, Pa. Jan. 25, 1907

SCARFE, GEORGE, Division Superintendent, Cailfornia Gas and Electric Co., Nevada City, Cal. Sept. 25, 1903

SCARLETT, WILLIAM, Engineer, United Telephone & Telegraph Co. of Philadelphia, 1825 N. 2nd St., Harrisburg, Pa. July 28, 1903

SCHABINGER, FREDERICK, Switchboard Operator, Interborough Rapid Transit Co.; res., 158 West 96th St., New York City. Mar. 24, 1905

SCHAEFER, EDWARD FRANKLIN, Poto Mines Corporation Rinconada Mining Co.; res., 242 West 136th St., New York City. June 21, 1907

SCHAFER, OLIVER MILTON, Superintendent, Fire Alarm and Police Telegraph, 30 W. State St., Trenton, N. J. Apr. 22, 1904

SCHARF, HENRY WARREN, Assistant Engineer, New York City Railway Co., 621 Broadway, New York City. July 28, 1903

SCHATTNER, ERNEST B., Schattner & Co., Caxton House, Westminster, S. W., London, Eng. Nov. 23, 1906

SCHAUS, CARL JOSEPH, Lighting Engineering Department, General Electric Co., res., 43 Front St., Schenectady, N. Y. Jan. 29, 1904

SCHEEL, HENRY VAN RIPER, Assistant to General Superintendent, MacAndrews and Forbes Co., Newark, N. J. Jan. 25, 1907

SCHERCK, LEON H., Superintendent Lighting Operating Dept., Ford Bacon & Davis, 24 Broad St., New York City. Sept. 28, 1906

SCHIAFFINO, MARIANO L., Chief Electrician, La Electra S. A., 2 Belen St., Guadalajara, Mexico. Feb. 28, 1900

SCHICK, DANIEL FREDERICK, Asst. Engineer Incandescent Lighting, Philadelphia Electric Co., Philadelphia, Pa. July 19, 1904

SCHIER, OTTO L. J., Electrical Draughtsman, New York Edison Co., 55 Duane St., New York City. Sept. 22, 1905

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SCHILDHAUER, EDWARD, Electrical and Mechanical Engineer, Isthmian Canal Commission, Washington, D. C. Nov. 22, 1901

SCHILLER, FRED WILLIAM, Foreman Meter Department, Utica Gas and Electric Co.; res., 168 Seymour Ave., Utica, N. Y. Apr. 28, 1905

SCHLOSSER, FRED G., Laclede Gas Light Co., 2721 Adams St., St. Louis Mo. Sept. 22, 1891

SCHLUEDERBERG, CARL GEORGE, 210 No. Craig St., Pittsburg, Pa. July 25, 1902

SCHLUSS, KURT, Superintendent of Power, Tacoma Railway and Power Co., Tacoma, Wash. Feb. 27, 1903

SCHMEISSER, ERNEST GAIL, Assistant Electrical Engineer, with George Gibbs, 10 Bridge St., New York City. Apr. 26, 1907

SCHMID, ERNEST E., 25 Beekman Place, New York City. Mar. 27, 1903

SCHMIDT, HENRY FREDERICK, Engineer, Douglass Robinson, Chas. S. Brown & Co., 160 Broadway, New York City. May 20, 1902

SCHMIDT, LAMBERT, President, The Lambert Schmidt Tel. Mfg. Co.,85 Maple St., Weehawken, N. J. Nov. 22, 1901

SCHMIDT, LOUIS MILTON, Engineer Alternating Department, General Electric Co.; res., 76 New Park St., Lynn, Mass. May 19, 1903

SCHMIDT, WALTER, Mechanical Engineer, Carnegie Steel Co., Newark, N. J. Apr. 23, 1903

SCHMITT, FREDERICK E., Associate Editor, *Engineering News*, 220 Broadway, New York City. Nov. 20, 1903

SCHNEIDER, CARL ALBERT, Connecticut, Co., Ford Building, New Haven, Conn. May 17, 1904

SCHNEIDER, GEORGE ARTHUR, Salesman, California Electric Co., 119 East 7th St., Los Angeles, Cal. Apr. 27, 1906

SCHNUCK, EDWARD FREDERICK, Production Engineer, Jabez Burns & Sons, 542 Greenwich St., New York City. Feb. 27, 1903

SCHOLES, DANIEL RANSOM, Chief Engineer, Aermotor Co., 12th and Rockwell Sts., Chicago, Ill. Mar. 29, 1907

SCHÖNHEIDER, RUDOLPH CHARLES, Chicago, Burlington and Quincy R. R.; res., Highwood, Minn. Apr. 23, 1903

SCHREIBER, GEORGE E., Consulting Engineer, Bary and Schreiber, 723 Mermod and Jaccard Bldg., St. Louis, Mo. Feb. 24, 1905

SCHREIBER, HERMAN VICTOR, 1301 Stephens Girard Building, Philadelphia, Pa. Sept. 25, 1903

SCHREIBER, MARTIN, Engineer, M. of W. Public Service Railway Co., Passaic Wharf, Newark, N. J. Apr. 23, 1903

SCHRENK, ARNOLD, Inspector, N. Y. C. & H. R. R.R., New York City. June 19, 1903

SCHRODER, BERNARD AUGUSTUS, Manager, Crocker-Wheeler Co., Hibernia Bank Building, New Orleans, La. Jan. 25, 1907

SCHROEDER, FREDERICK ALBERT, Superintendent Roll Department, Cambria Steel Co., Westmount, Johnstown, Pa. June 21, 1907

SCHUCHARDT, RUDOLPH FREDERICK, Electrical Engineer in Testing Laboratory, Chic. Edison Co., 139 Adams St., Chicago, Ill. Apr. 23,1903

SCHUERMANN, JULIUS, Manager, Star Electric Fuse Works, Wilkes-Barre, Pa. June 21, 1907

SCHUETZ, FREDERICK, Solicitor of Patents, 132 Nassau St., New York City; res., 55 Johnson Ave., Newark, N. J. Mar. 27, 1903

SCHÜLER, L., Electrical Engineer, Lahmeyer Co., Hochster Str. 45 Frankfurt A/M, Ger. May 17, 1904

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SCHUM, CHAS. H., Electrical Engineer, Burke Electric Co., Erie, Pa. Feb. 23, 1898

SCHUMACHER, JOHN HENRY, Assistant Superintendent of Construction, W. I. Gray & Co., Minneapolis, Minn. Mar. 1, 1907

SCHWAB, MARTIN C., Consulting Engineer, Adams & Schwab, 914 Republic Building, Chicago, Ill. Nov. 18, 1896

SCHWABACHER, FRANK, Stockton Milling Co., 112 California St.; res., 1900 Jackson St., San Francisco, Cal. May 17, 1904

SCHWABE, WALTER P., Supt. Rutherford Dist., The Gas and Electric Co., of Bergen Co., Rutherford, N. J. May 19, 1896

SCHWARTZ, CARL, Electrical Engineer, N. Y. C. & H. R. R.R., 5 Vanderbilt Ave.; res., 2100 FifthAve., New York City. Feb. 27, 1903

SCHWARZ, ELMER H., Electrical Engineer, 1125 Lexington Ave., New York City. Dec. 18, 1903

SCHWAUHAUSSER, FREDERICK, JR., Clerk, Charles Beseler Co.; 251 Centre St., New York City. Mar. 27, 1903

SCHWECKE, HENRY C., Electrical Engineer, General Electric Co.; res., 277 Glenwood Blvd., Schenectady, N. Y. Mar. 1, 1907

SCHWEITZER, EDMUND OSCAR, Testing Laboratory, Chicago Edison Co., 139 E. Adams St.; res., 1906 Oakdale Ave.,Chicago, Ill. Feb. 15, 1899

SCHWENNICKE, PAUL H., CHR., Manager of Berginhe Electric Works; res., 129 Croncuberger St., Solingen, Germany. May 19, 1903

SCLATER, ROBERTSON HOSKINS, Electrical Draftsman, Newport News Shipbuilding and Dry Dock Co., Hampton, Va. Mar. 29, 1907

SCOFIELD, EDWARD H., Electrical Engineer Twin City Rapid Transit Co., 2700 Blaisdell Ave., Minneapolis, Minn. May 19, 1903

SCOTT, ARTHUR CURTIS, Professor of Electrical Engineering, University of Texas, Austin, Texas. June 19, 1903

SCOTT, ALEXANDER HUGH, 512 Kelly St., Wilkinsburg, Pa. June 15, 1904

SCOTT, CHARLES RALPH, Central Office Manager, N. Y. and N. J. Telephone Co., Tompkinsville, N. Y. Oct. 26, 1906

SCOTT, CHESTER ARTHUR, Electrician, California Gas & Electric Corp., 1225 Octavia St., San Francisco, Cal. Dec. 15, 1905

SCOTT, GEORGE ALVIN, International Mfg. Co., 511 Woolworth Building, Lancaster, Pa. June 19, 1903

SCOTT, GEORGE WALKER, Electrical Engineer, Allis-Chalmers Co., The Bullock Electric Mfg. Co., Norwood, Ohio. Mar. 29, 1907

SCOTT, HERBERT ASHTON, Chief Engineer, Electrical Engineer, Horseshoe Forestry Co., Horseshoe, N. Y. Aug. 25, 1905

SCOTT, HOLTEN HENRY, with H. L. Doherty & Co., 60 Wall St., New York City. May 14, 1906

SCOTT, JAMES ALEXANDER, Erection Dept., Westinghouse Electric and Mfg. Co.,1004 New England Building,Cleveland, Ohio. Aug. 17, 1904

SCOTT, JAMES CROMBIE, City Electrical Engineer, Christchurch, New Zealand. July 19, 1903

SCOTT, QUINCY ADAMS, Electrical Engineering Department, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

SCOTT, ROBERT JULIAN, Professor of Engineering and Electricity, New Zealand University, Christchurch, New Zealand. Oct. 24, 1902

SCOTT, WILLIAM ARTHUR, Salesman, Westinghouse Electric and Mfg. Co., 716 Board of Trade Building, Boston, Mass. Apr. 28, 1905

SCOTT, WM. M., Electrical Engineer, The Cutter Electric and Mfg. Co., 19th and Hamilton Sts., Philadelphia, Pa. June 23, 1897

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SCOVILLE, GEORGE ALBERT, Engineer, Dean Electric Co., Elyria, O. Aug. 25, 1905

SCRIBNER, CHARLES E., Engineer, Western Electric Co., 259 South Clinton St., Chicago, Ill. Mar. 28, 1902

SCRUBY, ROBINETT, Assistant Works Manager, British L. M. Ericsson Mfg. Co., Ltd., Beeston Notts, Eng. Apr. 23, 1903

SCUDDER, HEWLETT, JR., General Electric Co., Schenectady, N. Y. Nov. 22, 1899

SEABROOK, HENRY HAMILTON, Manager, Westinghouse E. & M. Co., 1507 Continental Trust Building, Baltimore, Md. Jan. 24, 1902

SEAMAN, EDWIN HOPKINS, Electrical Engineer, Wantagh, L. I. Mar. 27, 1903

SEAMAN, HAROLD HIBBARD, Manager, Electric Storage Battery Co., 1127 Candler Bldg., Atlanta., Ga. Apr. 26, 1907

SEAMAN, JOSEPH B., Chief of Testing Dept., Philadelphia Electric Co., 122 Arch St., Philadelphia, Pa. May 19, 1903

SEARING, LEWIS, Vice-president and General Manager, Denver Engineering Works Co., 901 East Tenth Ave., Denver, Colo. Apr. 3, 1888

SEARLES, A. L., Electrical Engineer, Fort Wayne Electric Works, 222 Houseman Building, Grand Rapids, Mich. Apr. 18, 1894

SEARS, CHARLES ANDERSON, Superintendent of Power House, Puget Sound Power Co., Electron, Wash. Jan. 27, 1905

SEAVER, JAMES THATCHER, Chief Draughtsman, N. Y. C. and H. R. R.R. Co., 335 Madison, Ave.,New York City. Apr. 26, 1907

SEAVER, WALTER HIBBARD, Assistant Sales Agent, American Steel and Wire Co., 16th and Folsom Sts., San Francisco, Cal. June 21, 1907

SEDGWICK, C. E., Sales Dept., Ft. Wayne Electric Works, Ft. Wayne, Ind. Feb. 23, 1898

SEE, ALONZO B., A. B. See Electric Elevator Co., 220 Broadway, New York City; res., Lake Mahopac, N. Y. Jan. 17, 1893

SEE, PIERRE V. C., Car Inspector, Metropolitan West Side Elevated Railway; res., 405 64th St., Chicago, Ill. Dec. 23, 1904

SEEDE, JOHN AUGUSTINE, Designing Engineer, General Electric Co.; res., 133 Lafayette St., Shenectady, N. Y. Feb. 26, 1904

SEIDELL, THOMAS GRACEN, Georgia Railway and Electric Co.; res., 46 Irwin St., Atlanta, Ga. Apr. 28, 1905

SEIXAS, THEODORE GRISWOLD, Manager, American Instrument Co., Singer Building, New York City; res., Westfield, N.J. June 21, 1907

SELDEN, ANDREW KENNETH, JR., 82 W. 5th St., Bayonne, N. J. Apr. 23, 1903

SELDEN, GEORGE KEARSLEY, Construction Eng'r, Chesapeake & Potomac Telephone Co., 722 12th St., N.W., Washington, D.C. Mar. 1, 1907

SEMENZA, GUIDO, Chief Electrical Engineer, Italian Edison Co., of Milan, Via Tomaso Grossi 2, Milan, Italy. May 20, 1902

SEMPLE, BERT ERNEST, Meter Expert, General Electric Co.; res., 38 Walton Pl., Chicago, Ill. Nov. 21, 1902

SENSTIUS, SEBASTIAAN, Electrical Engineer, Triumph Electric Co., Cincinnati, Ohio. Feb. 27, 1903

SERGEANT, ELLIOT MATTHEWS, Roberts Chemical Co., res., 300 Jefferson Ave., Niagara Falls, N. Y. Nov. 25, 1904

SERINGHAUS, FREDERICK W., JR., General Electric Co.,; res., 954 8th Ave., New York City. May 14, 1906

SERRELL, ARTHUR HAROLD, Patent Solicitor, L. W. Serrell & Son, 302 Broadway, New York City; res., Brooklyn, N. Y. Mar. 25, 1904

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SERRELL, LEMUEL WM., Mechanical and Electrical Engineer, 29 Broadway, New York City; res., Plainfield, N. J. Nov. 1, 1887

SESSIONS, EDSON OLIVER, Sales Engineer, Stanley E. Mfg. Co., Monadnock Block, Chicago, Ill. Mar. 28, 1902

SESSIONS, FRANK LORD, Mechanical and Electrical Engineer, The Jeffrey Mfg. Co., Columbus, Ohio. Nov. 21, 1902

SESSIONS, WALTER SAMUEL, Electrical Engineer, 2896 Roxbury St., Los Angeles, Cal. Sept. 25, 1903

SEYFERT, STANLEY SYLVESTER, Instructor, Lehigh University; res., 425 Chestnut St., So. Bethlehem, Pa. Mar. 24, 1905

SHAAD, GEORGE CARL, Assistant Professor of Electrical Engineering, Massachusetts Institute of Technology, Boston, Mass. Feb. 27, 1903

SHALLCROSS, WILMER MIDDLETON, Assistant to Chief Electrician, By-Products Coke Corporation, So. Chicago, Ill. Sept. 28, 1906

SHANE, ADOLPH [*Local Secretary*], Acting Assistant Professor of Electrical Engineering, I. S. C., State College, Ames, Iowa. Dec. 23, 1904

SHARER, CARL WADSWORTH, Electrical Engineer, 2224 Tioga St., Philadelphia, Pa. Mar. 25, 1904

SHARP, CLAYTON HALSEY, Test Officer, Electrical Testing Laboratories, 80th St. & East End Ave., New York City. Feb. 28, 1902

SHARP, JOHN THOMAS, Chief Engineer, Canton Electric Light & Water Works, Canton, Miss. Dec. 15, 1905

SHARP, WILLARD CAULFIELD, Superintendent, Des Moines Edison Light Co., Des Moines, Iowa. Feb. 23, 1906

SHARPE, FREDERICK BASSETT, Manager, The Liberty Light and Power Co., Liberty, N. Y. May 19, 1903

SHAW, ALBION WALKER, Electrical Engineer, Stone & Webster, Engineering Corporation, 147 Milk St., Boston, Mass. Oct. 19, 1902

SHAW, ALONZO BENJAMIN, Electrical Engineer, Swift River, Mass. Sept. 25 1903

SHAW, AWBREY NORMAN, Robert Shaw's U. S. Bonded Warehouses, 65 Water St., New York City. Mar. 28, 1900

SHAW, FRED MENZIES, Tester, General Electric Co., Lynn, Mass. Apr. 22, 1904

SHAW, HENRY M., Treasurer, Shaw Engineering and Mfg. Co., Newark; res., 145 N. 17th St., East Orange, N. J. Feb. 24, 1905

SHAW, HOWARD BURTON, Professor Electrical Engineering, Missouri State University, Columbia, Mo. Apr. 28, 1897

SHAW, JOHN AITKEN, Engineer, 448 Lansdowne Ave., Westmount, Que. Aug. 17, 1904

SHAW, WILLIAM DAVIDSON, Engineering Department, Utah Light & Railway Co., Ogden, Utah. May 15, 1905

SHEAR, VERNE WARREN, Tester, Westinghouse Electric and Mfg. Co.; res., 511 Coal St., Wilkinsburg, Pa. Dec. 28, 1906

SHEARER, J. HARRY, Electrical Engineer, National Electric Light Co., Mexico City, Mexico. Jan. 24, 1900

SHELDON, EDWARD ELLIS, Member of Firm, Frost & Sheldon, 47 Hudson Ave., Albany, N. Y. Apr. 25, 1902

SHEPARD, BERT H., Special Agent, C. N. Y. T. & T. Co., Black River, N. Y. Sept. 28, 1906

SHEPARD, FRANCIS HENRY, Special Representative, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City. Apr. 26, 1907

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SHEPARD, FREDERICK MEAD, Northern Electrical Mfg. Co., Madison, Wis. Mar. 27, 1903

SHEPARD, LYMAN, Superintendent, Electric Light and Water Works, Edenton, N. C. Dec. 28, 1906

SHEPHERD, FRANK ROLAND, Assistant Engineer and Business Manager, Noyes Brothers; res., Roslyn, Dunedin, N. Z. Sept. 25, 1903

SHEPHERD, HARRY LAWRENCE, Assistant, Ralph D. Mershon, Street Railway Chambers, Montreal, Que. Aug. 25, 1905

SHEPHERD, JOSEPH, Electrical Engineer, London County Council Tramways, London, Eng. Nov. 24, 1905

SHEPPARD, ROBERT K., Sales Agent, American Steel and Wire Co., 809 Pennsylvania Bldg., Philadelphia, Pa. Sept. 28, 1906

SHERIDAN, MARTIN PHILIP, Chief Electrician Peregrina Mining and Milling Co., Peregrina, Guanajuato, Mex. Mar. 29, 1907

SHERWOOD, EDGAR F., Superintendent of Traffic, New York Telephone Co., 15 Dey St., New York City. Mar. 28, 1902

SHERWOOD, IRVING HOWARD, Electrical Engineer, Odenton, Md. May 19, 1903

SHIBUSAWA, MOTOJI, 9 Haraikata Enachi Ushigome, Tokyo, Japan. Mar. 24, 1905

SHIEBLER, MARVIN, Room 1102, 60 Wall St., New York City. Jan. 27, 1905

SHIMIDZU, SOICHIRO, Engineer, 8 First St., North Aoyama, Akasaka, Tokyo, Japan. Dec. 18, 1903

SHINJO, YOSHIO, Electrical Engineer, Tokyo Electric Co., Amishirocho, Azabuku, Tokyo, Japan. Feb. 24, 1905

SHIPLEY, PAUL RAVEN, Electrical Engineer, Salt Lake Electric Co., Salt Lake City. Utah. May 15, 1905

SHIPMAN, BENNET CARROLL, Consulting Electrical Engineer, Atlas Bldg., 604 Mission St., San Francisco, Cal. Jan. 23, 1903

SHIRAS, OLIVER, Engineer, Rome, N. Y. Mar. 24, 1905

SHIRLEY, JAMES JOSEPH, Partner, Mexican Steel Products and Machinery Co., Mexico City, Mexico. May 15, 1905

SHOCK, THOS. A. W., Electrical Engineer, York Haven Water and Power Co.; res., 224 Carlisle Ave., York, Pa. Mar. 20, 1885

SHOEMAKER, JOHN FRANKLIN, Master Mechanic, Warren, Springer Co., 197 So. Canal St., Chicago, Ill. Oct. 26, 1906

SHOVER, BARTON ROY, Electrical Engineer, Indiana Steel Co., Gary, Ind.; res., Chicago, Ill. June 21, 1907

SHREEVE, HERBERT EDWARD, Western Electric Co., 463 West St., New York City. Apr. 27, 1906

SHREVE, EARL OWEN, Supply Salesman, General Electric Co., Union Trust Building, San Francisco, Cal. Sept. 28, 1906

SHUFF, FRANK K., Chief Engineer, Iowa State College, Ames, Iowa. Mar. 1, 1907

SHUMAN, JOSEPH HENRY, Assistant Electrical Engineer, Boston Elevated Railway, 552 Harrison Ave., Boston, Mass. June 14, 1905

SHUSTER, JOHN WESLEY [*Local Secretary*], Assistant Professor of Electrical Engineering, Univ. of Wis., Madison, Wis. Jan. 3, 1902

SHUTE, HENRY DAMON,* Assistant to Vice-president, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 1, 1907

SIBLEY, ROBERT, Professor, Mechanical and Electrical Engineering Dept., University of Montana, Missoula, Mont. Oct. 23, 1903

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SIDDALL, JOSEPH J., Student, American Telephone and Telegraph Co., 908 Spruce St., Philadelphia, Pa. Jan. 25, 1907

SIEBER, FERDINAND, Electrical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburg, Pa. Aug. 17, 1904

SIEGFRIED, JOSEPH HENRY, Erecting Department, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Nov. 20, 1903

SIGOURNEY, WILLARD HENRY, Consolidated Railway Co.; res., 115 Greene St., New Haven, Conn. Mar. 27, 1903

SILVER, ARTHUR ELMER, Chief Electrician, Raleigh Electric Co., 745 Hillsboro St., Raleigh, N. C. June 21, 1907

SILVER, EARL D., Electrical Engineer, Western Electric Co., Hawthorne, Ill. May 19, 1903

SILVERMAN, MORTIMER, Electrical Engineer, Western New York and Pennsylvania Traction Co., Olean, N. Y. June 21, 1907

SIMON, ARTHUR, Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis. Sept. 25, 1903

SIMONS, IÖN, City Electrician, Charleston, S. C. June 19, 1903

SIMONTON, MARK, General Manager and Treasurer, the Electric Supply and Construction Co., Columbus, Ohio. Mar. 27, 1903

SIMPSON, ALEXANDER B., Electrical Engineer, 126 E. 41stSt,. New York City. May 21, 1891

SIMPSON, FREDERICK GRANT, Chief Engineer, Kilbourne & Clark Co., Seattle, Wash. Mar. 25, 1904

SIMPSON, GEORGE THOMAS, Consulting Engineer, 604 Pioneer Press Bldg. St. Paul, Minn. Jan. 25, 1907

SIMPSON, GEORGE W., Salesman, Westinghouse Electric and Mfg. Co.; res., 22 N. 59th St., Philadelphia, Pa. Mar. 29, 1907

SIMPSON, J. MANLEY, 960 Portland Ave., St. Paul, Minn. Jan. 25, 1899

SIMPSON, RICHARD CHRISTOPHER, Lecturer, Technical College, Sydney, N. S. W. Sept. 28, 1906

SIMPSON, THOMAS T., Consulting Engineer, 55 Spark St., Ottawa, Ont. Jan. 23, 1903

SINCLAIR, LINDLEY EDGAR, General Superintendent, Potomac Electric Power Co.; res., 3318 O St., Washington, D. C. July 28, 1903

SIRRINE, JOSEPH EMORY, Mill and Hydraulic Engineer, Greenville, S. C. Apr. 28, 1905

SISE, CHARLES F., President, Bell Telephone Co. of Canada, Montreal, Can. June 8, 1887

SKEHAN, EUGENE AUGUSTINE, Engineer, New York Edison Co., New York City; res., 913 St. Johns Pl., Brooklyn, N. Y. Mar. 1, 1907

SKELDING, ARTHUR BERTRAM, General Manager, Consolidated Railways Light and Power Co., Wilmington, N. C. June 19, 1903

SKIDMORE, JOHN JAMES, Engineering Department, American Telephone & Telegraph Co., 125 Milk St., Boston, Mass. Sept. 28, 1906

SKINNER, WILLIAM ELBERT, James Stuart Electric Co., Ltd., 88 Princess St., Winnipeg, Manitoba. Nov. 25, 1904

SKIRROW, JOHN F., Electrician, Postal-Telegraph Cable Co., 253 Broadway, New York City; res., East Orange, N. J. Sept. 25, 1895

SKOG, GUSTAF EMANUEL, Erecting Engineer, Elektriska Westeras, Sweden. May 17, 1904

SLADE, ARTHUR J., *Ph.D.*, Mechanical Engineer, Room 708, Times Bldg., New York City; res., 47 E. 58th St., New York City. Sept. 19, 1894

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SLADEN, HARRY S., Superintendent Street & Installation Dept., Portland General Electric Co., Portland, Ore. Oct. 27, 1905

SLATER, CLARENCE COULTER, General Superintendent, Columbus Public Service Co., Columbus, O. Jan. 27, 1905

SLATER, FREDERICK R., Electrical Engineer, 100 Broadway, New York City; res., 14 Arthur St., Yonkers, N. Y. Oct. 17, 1894

SLOAN, JAMES RICHARD, Electrician, Motive Power Dept., P. R.R., Altoona, Pa.; res., 607 West 61st Pl., Chicago, Ill. Feb. 28, 1902

SLOAN, MATTHEW SCOTT, Asst. Supt., Elect. Department, Birmingham Railway Light and Power Co., Birmingham, Ala. June 21, 1907

SLOANE, THOMAS O'CONOR, JR., General Contractor, 60 Wall St., New York City. Oct. 23, 1903

SLOANE, WILLIAM WOODARD, Draftsman, Western Electric Co.; Chicago, Ill. Dec. 28, 1906

SMALL, WILLIAM TELFORD, Instructor in Electrical Engineering, Purdue University; res., 427 Russell St., W. Lafayette, Ind. Jan. 25, 1907

SMALLPEICE, FRANK CLIPFORD, Engineer, Canadian General Electric Co., Ltd., Peterborough, Ont. Jan. 29, 1904

SMART, JOHN COWIE, Superintendent of Transmission Lines, Shawinigan Water and Power Co., Joliette, Que. Mar. 29, 1907

SMEATON, JAMES HUGH, Superintendent Generating Station, Winnipeg Electric Railway Co., Lac du Bonnet, Manitoba. June 21, 1907

SMITH, ALLARD, Superintendent of Construction, Chicago Telephone Co.; res., 1983 Kenmore Ave., Chicago, Ill. July 28, 1905

SMITH, ALGY J., Electrician in Charge Naval Proving Ground, Indian Head, Md. Mar. 29, 1907

SMITH, ARTHUR BESSEY, Purdue University, Lafayette, Ind. Mar. 25, 1904

SMITH, ARTHUR R., Electrical Engineer, General Electric Co.; res., 621 Terrace Pl., Schenectady, N. Y. Dec. 28, 1906

SMITH, CLEMENT ALFRED, Electrical Engineer, Chili Telephone Co., Casilla 397, Sanitago, Chili. Dec. 18, 1903

SMITH, DANIEL ARTHUR, Head of Electrical Department, Tuskegee Institute, Tuskegee, Ala. Apr. 26, 1907

SMITH, DANIEL SANFORD, Electrical Engineer, General Electric Co., 44 Broad St., New York City. Dec. 28, 1906

SMITH, DOW S., General Superintendent, Brooklyn Rapid Transit Co., Brooklyn, N. Y. July 28, 1903

SMITH, ERNEST FRANK, Superintendent of Sub-Stations, Chicago Edison Co., 139 Adams St., Chicago, Ill. June 21, 1907

SMITH, ELLIS BURTON, Assistant Factory Engineer, Western Electric Co., 463 West St., New York City. Dec. 28, 1906

SMITH, EMOR A., Wire Chief, Southern N. E. Telephone Co.; res., 427 Main St., Hartford, Conn. Dec. 18, 1903

SMITH, FRANCIS C., Gen. Supt. Harry Alexander, 18 West 34th St.; res., 912 Home St., New York City. Jan. 23, 1903

SMITH, FRANK WARREN, Manager, Sundh Electric Co., 115 Cedar St., New York City. Sept. 27, 1901

SMITH, FRANK WHITNEY, Secretary, United Electric Light and Power Co., 1170 Broadway, New York City. Apr. 28, 1905

SMITH, GEORGE WALLACE, Tutor, Electrical Engineering, University of Texas; res., 1908 Whitis Ave., Austin, Texas. June 21, 1907

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SMITH, HARRISON ARTHUR, Salesman, General Electric Co., Chicago, Ill. Apr. 23, 1903

SMITH, HARRISON WILLARD, Instructor of Electrical Engineering, Mass. Institute of Technology, Boston, Mass. Jan. 29, 1904

SMITH, HARTLEY LE HURAY, Chief of Testing Bureau, Brooklyn Hts. R.R. Co., Kent & Division Aves., Brooklyn, New York. Nov. 25, 1904

SMITH, HENRY LAWRENCE, Electrical Engineer, General Electric Co.; res., 23 State St., Schenectady, N. Y. May 15, 1905

SMITH, HERBERT WILMONT, Salesman, Stanley Electric Mfg. Co., Oliver Bldg., 141 Milk St., Boston, Mass. Mar. 24, 1905

SMITH, HOWARD F., Engineer, H. H. Humphrey Chemical Building, St. Louis, Mo. Apr. 23, 1903

SMITH, IRVING WILLIAMS, Electrician, Bishop Gutta Percha Co., 420 E. 25th St.; res., 5 W. 90th St., New York. Jan. 9, 1901

SMITH, JOSEPH ALLEN, General Electric Co., 44 Broad St., New York City. Jan. 23, 1903

SMITH, J. BRODIE, General Manager, Manchester Traction, Light and Power Co., 46 Hanover St., Manchester, N. H. Mar. 21, 1894

SMITH, JAMES MACDONALD, Electrical Engineer, Crocker-Wheeler Co., Ampere; res., 95 North 19th St., East Orange, N. J. June 21, 1907

SMITH, JAMES NORMAN, Electrical Engineer, Ross & Holgate, 80 St. Francois Xavier St., Montreal, P. Q. Mar. 27, 1903

SMITH, JOHN HAYES, President *Electrical Age*, 45 E. 42d St., New York City. Mar. 27, 1903

SMITH, JULIAN CLEVELAND, Superintendent, Shawinigan Water ard Power Co., Bank of Ottawa Bldg., Montreal, P. Q. Nov. 20, 1903

SMITH, LEONARD GRANT, Chief Clerk to General Manager, 1001 Royal Insurance Bldg., Chicago, Ill. Oct. 27, 1905

SMITH, LESTER, Meter Department, Philadelphia Electric Co., 122 Arch St., Philadelphia, Pa. Jan. 29, 1904

SMITH, LOUIS CLARENCE, Foreman of Meter Wireman, etc., Edison Electric Light Co., of Philadelphia; res., Woodbury, N. J. Apr. 23, 1903

SMITH, OBERLIN, President and Mechanical Engineer, Ferracute Machine Co., Lochwold, Bridgeton, N. J. May 19, 1891

SMITH, RAYMOND WESTHORPE, Inspector, N. Y. C. and H. R. R.R. Co., Engineering Department, New York City. Apr. 26, 1907

SMITH, ROBERT ARMSTRONG, JR., Engineer, J. G. White Co., 43 Exchange Pl., New York City. Oct. 27, 1905

SMITH, ROBERT JAMES, Superintendent, Canadian Electric and Water Power Co., Ltd., Perth, Ont. May 17, 1904

SMITH, SAMUEL HOLMES, JR., Engineer, Stanley Electric Mfg. Co., Empire Bldg., Atlanta, Ga. Feb. 26, 1904

SMITH, SAMUEL JAMES, 202 So. Tryon St., Charlotte, N. C. Oct. 24, 1900

SMITH, SAMUEL NEWTON, President, North Shore Reduction Co., Ltd., of Ontario, 424 Andrus Building, Minneapolis, Minn. Oct. 25, 1901

SMITH, SAMUEL WILLIAM, Engineer & Salesman, Packard Electric Co., Room 400 Lindsay Building, Montreal, Que. Sept. 27, 1901

SMITH, SETH BARTON, District Manager, Canadian Westinghouse Co., Ltd., Vancouver, B. C. Mar. 1, 1907

SMITH, THOMAS P., Assistant Chief Operator, Postal Telegraph & Cable Co., 253 Broadway, New York City. Sept. 28, 1906

SMITH, VINTON, Student, Brooklyn Polytechnic Institute; res., 34 South Oxford St., Brooklyn, N. Y. Apr. 26, 1907

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SMITH, WALTER CHARLES, General Electric Co.; res., 1009 Union St., Schenectady, N. Y. Mar. 29, 1907

SMITH, WALTER EUGENE, Electrician, The United States Navy Department, Midvale Steel Works, Philadelphia, Pa. Feb. 28, 1900

SMITH, WALTER F., 412 U. G. I. Bldg.; res., 2010 Ontario St., Philadelphia, Pa. July 26, 1900

SMITH, WILLIAM JOHN, Manager, Wallace-Smith & Co., 19 Murray St., New York City. Jan. 26, 1906

SMITH, WILLIAM MCALLISTER, Telephone Engineer, Western Electric Co.; res., 301 E. 68th St., New York City. Mar. 29, 1907

SMITH, WM. STUART, U. S. N., 2538 Dwight Way, Berkely, Cal. July 26, 1901

SMITH, WILLIAM NELSON, Electrical Engineer, Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. Mar. 28, 1902

SMOUT, ALLEN, District Mains Superintendent, 31 Connaught St., Hyde Park, W. London, Eng. Jan. 25, 1907

SMYTHE, EDWIN HUTCHISON, Expert in patent causes, 738 Monadnock, Chicago; res., Freeport, Ill. Apr. 23, 1903

SNOOK, HOMER CLYDE, Manager, Roentgen Manufacturing Co.; res., 5414 Norfolk St., Philadelphia, Pa. Sept. 22, 1905

SNOW, JOHN E. [*Local Secretary*], Associate Professor in E. E. Department, Armour Institute of Technology, Chicago, Ill. Mar. 27, 1903

SNOWDEN, LAWRENCE WILMER, Foreman, Rowland Telegraphic Co., 107 E. Lombard St., Baltimore, Md. Dec. 15, 1905

SNYDER, ALLEN LANE, Electrical Engineer, Seattle Electric Co., Seattle, Wash. Nov. 23, 1906

SNYDER, FREDERICK TITCOMB, Treasurer, Canada Zinc Co., Vancouver, B. C.; res., Oak Park, Ill. May 15, 1905

SNYDER, HARRY RAY, Erecting Department, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Nov. 25, 1904

SNYDER, HENRY NICHOLAS, Santa Paula, Cal. Apr. 22, 1904

SNYDER, NATHANIEL MARION, 192 Dearborn Ave., Kankakee, Ill. Nov. 23, 1900

SNYDER, RICHARD ANDREW LEE, Construction Engineer, Central District & Printing Telegraph Co., Pittsburg, Pa. Jan. 25, 1907

SOANS, CYRIL ARTHUR, Electrical Engineer, Bell Selector Telephone Co., 1703 Melrose St., Chicago, Ill. June 21, 1907

SOLOMON, NATHAN CLARENCE, with Harry Alexander, 15 W. Fayette St., Baltimore, Md. Aug. 22, 1902

SOMERS, LOUIS A., Westinghouse Electric & Mfg. Co., 2d & Howard Sts., San Francisco, Cal. June 14, 1905

SOREN, TOWNSEND HODGES, Electrical Engineer, General Electric Co., Schenectady, N. Y. Nov. 22, 1901

SOUTHWORTH, MARTIN O., Engineer of Electrical Dept., Fairbanks, Morse & Co., Chicago, Ill. Feb. 27, 1903

SOWERS, DAVID W., President, H. W. Dopp Co., 1300 Niagara St.; res., 834 Auburn Ave., Buffalo, N. Y. July 18, 1899

SOXMAN, GEORGE MEADE, Constructing Telephone Engineer, Southwestern Tel. and Tel. Co., 335 State St., Dallas, Tex. Dec. 15, 1905

SPALDING, EDWARD BURSON, Electrician, Aluminum Co. of America East St. Louis, Ill. Apr. 26, 1907

SPALDING, PHILIP LEFFINGWELL, Engineer, The Bell Telephone Co., Philadelphia, Pa. May 20, 1902

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SPALDING, SAMUEL ALBERT, Superintendent of Power, Brooklyn Heights R.R. Co., 168 Montague St., Brooklyn, N. Y. May 15, 1905

SPALDING, WILL, Draughtsman, Illinois Traction System; res., 530 W. Main St., Decatur, Ill. Jan. 29, 1904

SPAULDING, PLINY P., Foreman of Experimental R.R., General Electric Co.; res., 160 Brandywine Ave., Schenectady, N. Y. Mar. 27, 1903

SPEAR, JAMES OTIS, JR., Fort Wayne Electric Works, 1013 Empire Bldg., Atlanta, Ga. Feb. 26, 1904

SPECHT, HANS CHRISTIAN, Electrical Engineer, Westinghouse Electric and Mfg. Co., East Pittsburg, Pa. Dec. 23, 1904

SPEIRS, CHARLES EDWARD, Manager, D. Van Nostrand Co., 23 Murray St., New York City; res., 2175 83d St., Brooklyn, N. Y. Dec. 19, 1902

SPEIRS, CHARLES WILLIAM, Managing & Tech. Director, Morgan Crucible Co., Ltd., Battersea Works, London, S. W., Eng. Mar. 23, 1906

SPELLMIRE, WALTER B., Allis-Chalmers Co., 814 Frick Building, Pittsburg, Pa. May 21, 1901

SPENCER, CHAS. J., Editor, *Electrical Age*, 45 E. 42d St., New York City. May. 21, 1901

SPENCER, ELBERT ROY, Assistant Editor, *Electric Journal*, Pittsburg, Pa. Mar. 29, 1907

SPENCER, EUGENE JACCARD, Consulting Engineer, 400 Merchants' Laclede Bldg., St. Louis, Mo. Dec. 28, 1906

SPENCER, FREDERICK FURMON, Assistant Engineer, Mexico General Electric Co., Mexico, Mex. Feb. 27, 1903

SPENCER, HENRY JOHN, Electrical Engineer, Hobart Gas Co., Hobart, Tasmania. Jan. 26, 1906

SPENCER, PAUL, Inspector of Electric Plants, United Gas Improvement Co., Broad and Arch Sts., Philadelphia, Pa. Nov. 30, 1897

SPENCER, THOMAS, Electrician, Helios Manufacturing Co., Bridesburg, Philadelphia, Pa. May, 19, 1903

SPENGEL, HERMANN GEORGE, General Manager, Rand Central Electric Works, Ltd., Johannesburg, Transvaal, S. A. Sept. 26, 1902

SPERLING, R. H., Assistant Engineer, British Columbia Electric Railway Co., Ltd., Vancouver, B. C. Nov. 23, 1898

SPIEGEL, ALEXANDER S., Eng'g Dept., Chicago Telephone Co., 203 Washington St.; res., 1955 Deming Place, Chicago, Ill. Dec. 23, 1904

SPIES, ALBERT, Editor, *The Electrical Record*, 123 Liberty St., N. Y. City; res., 40 Glenwood Ave., Jersey City, N. J. Oct. 28, 1904

SPOEHRER, HERMANN, Union Electric Light and Power Co., 10th and St. Charles Sts., St. Louis, Mo. Sept. 27, 1901

SPORBORG, H. N., Electrical Engineer, British Thomson-Houston Co., Rugby, Eng. July 25, 1902

SPRINGER, FRED FOSTER, Telephone Engineer, Pacific States Tel. and Tel. Co., 216 Bush St., San Francisco, Cal. May 15, 1905

SPRINGSTEEL, WILLIAM EUGENE, Chief Engineer, Weil & Mayer, 580 Broadway, New York City. Jan. 27, 1905

SPRONG, SEVERN D., United Electric Light & Power Co., 1170 Broadway, New York City. Mar. 27, 1903

SPURLING, OLIVER CROMWELL, Assistant Plant Engineer, Western Electric Co., 259 So. Clinton St., Chicago, Ill. Feb. 27, 1903

SPURRIER, JOHN RUDOLPH, Superintendent Fibre Conduit Co., Orangeburg, N. Y. Sept. 25, 1903

SQUIER, GEORGE O., Major, *Ph.D.*, Assistant Commandant U. S. A. Signal School, Fort Leavenworth, Kansas. May 19, 1891

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Squire, William John, Manager, Squire Electric Co., 113 E. 8th St., Kansas City, Mo. Sept. 28, 1906

Stabler, Harold Brooke, Chief Inspector, Chesapeake and Potomac Telephone Co.; res., 1214 I St., Washington, D. C. Feb. 26, 1904

Stadermann, Albert Leo, Engineer, Citizen's Independent Telephone Co., 120 South St., Terra Haute, Ind. June 19, 1903

Stafford, Rex Thomas, District Engineer, Allis-Chalmers Co.; res., 126 Cottage St., Buffalo, N. Y. Nov. 20, 1903

Stakes, D. Franklin, Electrical Engineer, Westinghouse Electric & Mfg. Co., Philadelphia, Pa. Jan. 20, 1897

Stål, Gustaf, Electrical Designer, Allmanna Svenska Elektriska Aktiebolaget, Elektriska, Westeras, Sweden. Mar. 24, 1905

Stalberg, Sven Olaf, Draftsman, General Electric Co.; res., 81 N. Common St., Lynn, Mass. Apr. 23, 1903

Stanbrough, Duncan G., Master Electrician, U. S. Navy Yard, Norfolk, Va. Sept. 28, 1906

Stanley, George James, Electrical Engineer, Aluminum Co. of America; res., Poqueto Club, Parnassus, Pa. Apr. 26, 1907

Stanley, Howard Arthur, Construction Department, General Electric Co., Schenectady, N. Y. Mar. 1, 1907

Stansel, Numa Reid, Inspector of Mechanical & Electrical Engineering 477 Federal Building, Chicago, Ill. Mar. 27, 1903

Stanton, Willard James, General Superintendent, Corn Belt Telephone Co., Waterloo, Ia. Jan. 25, 1907

Startsman, Charles Wentworth, Sales Department, Crocker-Wheeler Co., Ampere, N. J. June 19, 1903

Starzinger, Otto, Salesman, Fort Wayne Electric Works, 325 Lincoln Trust Bldg., St. Louis, Mo. Sept. 28, 1906

Stebbins, George Alfred, Secretary and Erecting Engineer, Stebbins Engineering & Mfg. Co., Watertown, N. Y. Sept. 28, 1906

Stebbins, Rowland, Engineering Salesman, Westinghouse Electric & Mfg. Co.; res., 6 E. 41st St., New York City. Apr. 26, 1907

Steck, Ernst, Engineer, Dodge and Day, Drexel Bldg., Philadelphia, Pa. May 14, 1906

Steck, Robert, Designing Electrical Engineer, Western Electric Co., 259 So. Clinton St.; res., 1520 Wolfram St., Chicago, Ill. Apr. 23, 1903

Steele, J. Herbert, 580 State St., Springfield Mass. May 19, 1903

Steele, Walter D., Electrical Engineer, Benjamin Electric Mfg. Co., 42 West Jackson Blvd., Chicago, Ill. Apr. 25, 1900

Steen, Harry Andrew, Designer of Electrical Apparatus, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. June 21, 1907

Stein, Herman Kroberger, Erecting Engineer, Westinghouse Electric and Mfg. Co., 730 Board of Trade Bldg., Boston, Mass. Apr. 26, 1907

Steinmetz, Edward George, Asst. Supt., The Electric Storage Battery Co., 19th St. and Allegheny Ave., Philadelphia, Pa. Sept. 26, 1902

Stenger, Lawrence A., Engineering Staff, Twin City Rapid Transit Co.; res., 313 3d Ave., S. E. Minneapolis, Minn. Dec. 28, 1906

Stephens, Arthur Harlan, Engineer, 812 West Mercury St., Butte, Mont. Nov. 21, 1902

Stephenson, Harry Lucien, Westinghouse Electric and Mfg. Co., 1107 Traction Bldg., Cincinnati, Ohio. June 14, 1905

Stephensen, Oddgeir, Department of Electrical Engineering, University of Illinois, Urbana, Ill. Apr. 27, 1906

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STERN, PHILIP KOSSUTH, Practising Electrical and Mechanical Engineering, 521 W. 182d St., New York City. Nov. 28, 1900

STERNEFELD, ISIDORE, Manager, Electrical Department, G. & O. Braniff & Co., Callé Cadena 19, Mexico, Mex. June 19, 1903

STETSON, ALMON BEEDE, Electrical Engineer, American Tel. & Tel. Co., 125 Milk St., Boston; res., Malden, Mass. Apr. 28, 1905

STEUART, WILLIAM, Partner Steuart & Fenn, Auckland, N. Z. June 19, 1903

STEVENS, CABOT, Electrical Engineer, Columbus Power Co., Columbus, Ga. June 28, 1901

STEVENS, OSCAR EGERTON, General Railway Signal Co., Rochester, N. Y. Apr. 26, 1907

STEVENS, THEODORE, Electrical Engineer, British Thomson Houston Co.; res., 26 Montalt Road, Woodford, Eng. Oct. 27, 1905

STEVENS, WILLIAM NORTON, Assistant Mechanical Engineer, J. G. White & Co., 43 Exchange Pl., New York City. Dec. 15, 1905

STEVENSON, EDWARD WILLIAM, Hazard Mfg. Co.; res., 402 South River, Wilkesbarre, Pa. Mar. 27, 1903

STEVENSON, FRANCIS LESLIE, Electrical Engineer, International Harvester Co., 7 Monroe St., Chicago Ill. Sept. 25, 1903

STEVENSON, JOHN MCALLISTER, JR., 28 Reed St., Pittsfield, Mass. June 14, 1905

STEWART, GEORGE WIGRAM, Manager, Victorian Branch, Standard Electric Elevator Co., Melbourne, Victoria. Feb. 23, 1906

STEWART, JAMES A., Superintendent of Plant, New York & New Jersey Telephone Co., 15 Dey St., New York City. July 26, 1907

STEWART, MILES VINCENT, Commercial Engineer, General Electric Co., Schenectady, N. Y. May 14, 1906

STEWART, NEWELL COE, JR., General Electric Co., 681 Ellicott Square, Buffalo, N. Y. May 15, 1905

STEWART, RICHARD GLYDE, General Foreman Memphis Street Railway Co., 586 Lauderdale St., Memphis, Tenn. Mar. 29, 1907

ST. GEORGE, HARRY LUXMOORE, with Ralph D. Mershon, 60 Wall St., New York City. Mar. 27, 1903

STICKNEY, GEORGE HOXIE, Electrical Engineer, General Electric Co.; res., 51 Tudor St., Lynn, Mass. Feb. 26, 1904

STICKNEY, JOSEPH WHITE, Central Union Tel. Co., Anderson, Ind. Mar. 27, 1903

STIELER, FREDERICK CARL, Engineering Department, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Mar. 29, 1907

STILLMAN, HARRY NOYES, Instructor Electrical Engineering, Spring Garden Institute, Philadelphia, Pa. June 21, 1907

STILWELL, TOM KENNAN PRICE, Assistant Illuminating Engineer, General Electric Co., Lynn, Mass. Apr. 23, 1903

STIMPSON, CLARENCE ARNEY, Installation Bureau, Philadelphia Electric Co., 122 Arch St., Philadelphia, Pa. May 17, 1904

STINE, WILBUR M., Professor of Engineering, Swarthmore College, Swarthmore, Pa. May 15, 1894

STINEMETZ, WILLIAM RENRICK, 1531 P Street, Washington, D. C. Apr. 23, 1903

STIRLING-THORPE, JOHN EDWARD, Superintendent Electrical Equipment, S. A. Luz Electrica, San Juan, P. R. Apr. 27, 1906

STITES, RICHARD, Secretary Electric Supply and Construction Co., 80 E. Gay St., Columbus, O. Feb. 26, 1904

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STOCKBRIDGE, GEO. H., Patent Attorney, 111 Broadway; res., 2514 11th
[Life Member.] Ave., near 187th St., New York City. May 24, 1887

STOCKER, LEOPOLD, 1st Class Sergeant, Signal Corps, U. S. Army, Ft. Strong, Boston, Mass. Sept. 22, 1905

STOCKTON, JOHN, Electrical Engineer, W. F. Whittemore, 1 Newark St.; res., 1221 Washington St., Hoboken, N. J. June 14, 1905

STOCKWELL, JOSEPH FRANCIS, Asst. General Manager, Keystone Telephone Co., Philadelphia, Pa. June 19, 1903

STODDARD, HARRY CABLE, Superintendent, Condor Water and Power Co., Tolo, Ore. Nov. 24, 1905

STOKES, HUGH GREGORIE, Engineer, Hall Bros., Dadeville, Ala. June 15, 1904

STOLL, CLARENCE GRIFFITH, Telephone Engineer, Western Electric Co., 259 So. Clinton St., Chicago, Ill. Apr. 26, 1907

STONE, CHARLES LE ROY, Manila Railway and Lighting Co., Manila, P. I. Oct. 24, 1902

STONE, FRANK J., Manager, Electric Storage Battery Co., 60 State St., Boston; res., 66 Highland Ave., Somerville, Mass. Mar. 25, 1904

STONE, JOSEPH P., Oficina de Talleres, Ferro Carril Oeste de Buenos Aires Estacion Linieres, F. C. O., Buenos Aires, A. R. Dec. 18, 1895

STONE, ROX LYNNE, Student, Cornell University; res., 408 Eddy St., Ithaca, N. Y. Jan. 25, 1907

STONE, WILLIAM, Electrical and Lighting Engineer, The Victoria Railway; res., 17 Doona Ave., Melbourne, Victoria. June 19, 1903

STONEY, MALCOLM PERCY, Partner, Philadelpha Engineering Co., 333 Heed Bldg., Philadelphia, Pa. Sept. 28, 1906

STORER, SIMON BREWSTER, Consulting Electrical Engineer, 732 University Block, Syracuse, N. Y. Apr. 25, 1902

STOVEL, RUSSEL WELLESLEY, Electrical Engineer, Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. Apr. 25, 1902

STOVER, JOSEPH WOODMAN, President Gamewell Fire Alarm Telegraph Co., 19 Barclay St., New York City. June 15, 1904

STOVER, RODERICK, Albuquerque, New Mexico. Aug. 22, 1902

STOWE, FRANK RABINEAU, Operator, Power Transit and Light Co., Bakersfield, Cal. June 21, 1907

STRASBURGER, EDGAR, Assistant in Cable Department, Western Electric Co., 463 West St., New York City. Mar. 27, 1903

STRASZEWSKI, CASMIR RICHARD, Westinghouse Electric & Mfg. Co.; res., 515 Elliot St., Pittsburg, Pa. May 15, 1905

STRATTON, SAMUEL W., Director, National Bureau of Standards, Washington, D. C. May 17, 1904

STRAUB, ALBERT RUDOLPH, Foreman, Western Electric Co., 463 West St., New York City. June 14, 1905

STAUFFER, HENRY E., Assistant Examiner, U. S. Patent Office, Washington, D. C. Sept. 28, 1906

STRAUS, THEODORE E., Electrical Engineer, Maryland Life Building, 10 South St., Baltimore, M. D. Nov. 18, 1896

STREET, CLEMENT F., 40 Lafayette St., New Rochelle, N. Y. Jan. 27, 1905

STREET, GEORGE TATUM, Stone & Webster, Engineering Corp., 147 Milk St., Boston, Mass. Dec. 19, 1902

STREETER, STEVENS DANA, Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. Mar. 23, 1906

STRENG, LEWIS STARR, Chief Engineer, Kentucky Electric Co., Louisville, Ky. May 17, 1904

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STRICKLAND, TOM PERCIVAL, Chief Assistant Electrical Engineer, 51 Philip St., Sydney, N. S. W. Nov. 25, 1904

STRIKE, ROBERT JOHN, Mains Engineer and Technical Assistant, Launceston Corporation, Town Hall, Launceston, Tasmania. Jan. 29, 1904

STROHMAN, WILLIAM, Engineer, Gorochovaya 61, St. Petersburg, Russia. Apr. 22, 1904

STRONG, JAMES REMSEN, President, The Tucker Electric Construction Co., 35 So. William St., N. Y.; res., Short Hills, N. J. Mar. 22, 1901

STRONG, RUSH PRICE, Electrician, Louisiana Fire Prevention Bureau, 807 Hibernia Bldg., New Orleans, La. Jan. 23, 1903

STUBBS, WILBUR SEWALL, Guinle & Co., Rio Janeiro, Brazil. May 14, 1906

STUEVE, CARL A. E. G., Electrical Engineer, with C. O. Mailloux, 76 William St., New York City. Apr. 23, 1903

STUNTZ, ALBERT WELLS, Designing Electrical Engineer, Morgan Engineering Co., Alliance, Ohio. Apr. 27, 1906

STURDEVANT, CHAS. RALPH, Electrical Engineer, American Steel & Wire Co., Worcester, Mass. May 16, 1899

STURGES, HARRY WILTON, Electrical Engineer, American Tool and Machine Co. of Boston, Mass. Apr. 26, 1907

STURGES, WARD LEE, Electrical Engineer, Bush Terminal Co., Brooklyn, N. Y.; res., 204 W. 105th St., New York City. Jan. 23, 1903

STURGESS, GEORGE MEYNELL, Superintendent of Electrical Department, Lackawanna Steel Co., Buffalo, N. Y. Sept. 28, 1906

STURGIS, EDWIN ALBERT, Superintendent of Equipment, Mass. Elec. Co., 84 State St., Boston, Mass. Feb. 24, 1905

STUTZ, CHAS. C., Assistant Chief Engineer, Pittsburg Plate Glass Co., Frick Building, Pittsburg, Pa. Mar. 28, 1900

SUGIYAMA, SEIJIRO, Municipal Electric Railway Dept., City Hall, Osaka, Japan. Mar. 25, 1904

SUHR, OTTO BRUNO, Engineer, The Telluride Power Co., Provo, Utah. July 19, 1904

SULLIVAN, JEREMIAH W., Chief Operator, Postal Telegraph Cable Co.; res., Stafford House, Buffalo, N. Y. June 15, 1904

SUMMERS, LELAND L., Electrical Engineer, Barberton, Ohio. Feb. 16, 1892

SUMMERHILL, ERNEST JOHN, Supervising Engineer, Br. Westinghouse Electric and Mfg. Co., Ltd., London, England. Mar. 1, 1907

SUNDHEIMER, ARTHUR ISAAC, Student, Columbia University; res., 234 W. 137th St., New York City. Apr. 26, 1907

SUTHERLAND, HENRY T., Electrical Engineer, 1233 Appletree St., Philadelphia, Pa. June 14, 1905

SUTTER, FREDERICK C., Member, Pittsburg Transformer Co., Pittsburg, Pa. Dec. 18, 1903

SUTTON, FRANK, Consulting Electrical Engineer, 91 Wall St., New York City. Apr. 26, 1907

SWAIN, JOSEPH GORDON, Erecting Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Apr. 28, 1905

SWEENEY, BAYARD K., Manager of Denver Sales Office, The N. Y. Insulated Wire Co., etc., 708 Equitable Bldg., Denver, Col. Mar. 27, 1903

SWEENY, JOHN EDWARD, Chief Clerk, Department of Electricity, Jamestown Exposition Co., Pine Beach, Va. June 21, 1907

SWEET, HORACE BRIMMER, Electrical Engineer, Utica, N. Y. Dec. 15, 1905

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SWEETLAND, RALPH, Electrical Inspector, New England Insurance Exchange, 55 Kilby St., Boston; res., Natick, Mass. Oct. 25, 1901

SWEETSER, PHILIP STARR, Paducah Light and Power Co., Paducah, Ky. Sept. 22, 1905

SWINK, DAVID MAXWELL, Superintendent, Winchester & Washington City Ry. Co., Winchester, Va. Aug. 17, 1904

SWITZER, GEORGE H., Bath, N. Y. Feb. 27, 1903

SWOBODA, ADOLPH RUDOLPH, Engineering Dept., Kellogg Switchboard Supply Co.; res., 5141 Morgan Ave., Chicago, Ill. Sept. 28, 1906

SWOPE, GERARD, Power Apparatus Manager, Western Electric Co., 259 So. Clinton St., Chicago, Ill. Apr. 26, 1899

SYKES, FREDERICK GEORGE, Electrical Engineer, Portland General Electric Co., Portland, Ore. May 19, 1903

SYKES, HENRY H., Gen. Supt., Southern New England Telephone Co., New Haven, Conn. Oct. 18, 1893

SYKES, HENRY WALTER, Electrical Engineer, Solvay Process Co., Syracuse, N. Y. June 14, 1905

SYMES, HARRY, Superintendent, Electrical Development Co., Niagara Falls, N. Y. Mar. 29, 1907

SZUK, GEZA, Chief Engineer, Ganz & Co.; res., Csalogany utcza 52 Budapest 11, Hungary. Jan. 3, 1902

TABER, SILAS, Moravian Electric Light, Heat and Power Co., Moravia, N. Y. Mar. 27, 1903

TACHIHARA, JIN, Electrical Engineer, Mitsu Bishi Dockyard & Engine Works, Kobe, Japan. Jan. 26, 1898

TADA, SHIGEKANE, Lieut., Kure Naval Arsenal, Kure, Japan. Mar. 27, 1903

TAGGART, RALPH CONE, Associate Engineer, Wm. J. Baldwin; res., 311 W. 95th St., New York City. Dec. 28, 1906

TAIT, FRANK M., Dayton Electric Light and Power Co., Dayton, O. Sept. 19, 1894

TALBOT, RICHMOND, Partner, Sanderson & Porter, 35 William St., New York City; res., Tuxedo, N. Y. July 25, 1902

TALBOTT, WILLIAM MAURICE, Superintendent, Red Telephorica, 20 Zulu-etra St., Havana, Cuba. Dec. 23, 1904

TAMLYN, WALTER IRVING, Electrical Engineer, with Ralph D. Mershon, 60 Wall St., New York City. Mar. 27, 1903

TAPLEY, WALTER H., Walker Electric Co., 23d & Noble Sts., Philadelphia, Pa. Oct. 25, 1892

TAPPING, CHESTER HARTRANFT, Assistant Superintendent Edison Electric Illuminating Co., 3 Head Place, Boston Mass. Apr. 27, 1906

TATEM, CLIFFORD ROSS, Technical Salesman, Allis-Chalmers Co., Buffalo, N. Y. Mar. 1, 1907

TAUSSIG, WILLIAM S., Sales Engineer, Western Electric Co., 259 So. Clinton St., Chicago, Ill. Mar. 29, 1907

TATUM, LEWIS LEEDS, Cutler Hammer Mfg. Co., Milwaukee, Wis. Feb. 27, 1903

TAUBENHEIM, ULRICH E., Manager, City Water Works, Archangel, Russia Nov. 24, 1905

TAYLOR, ALBERT, Manager, New York Office, Electric Storage Battery Co., 100 Broadway, New York City. May 21, 1901

TAYLOR, CHARLES HENRY, Assistant Engineer, Marconi Wireless Telegraph Co. of America, South Wellfleet, Mass. June 21, 1907

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TAYLOR, EDWARD, Engineer, Brooklyn Heights Rd. Co., 2075 Broadway; res., 373 Hawthorne St., Brooklyn, N. Y. Apr. 28, 1905

TAYLOR, EDWARD R., Manufacturing Chemist, Penn Yan, N. Y. Jan. 23, 1903

TAYLOR, FRANK H., Yale & Towne Mfg. Co., 9 Murray St.; res., 995 Madison Ave., New York City. Jan. 3, 1902

TAYLOR, HENRY WILLIAM, Designing Engineer, British Thomson Houston Co., Ltd.; res., Henry St., Rugby, Eng. Mar. 1, 1907

TAYLOR, JEREMY F., Cero de Pasco Co., Cero de Pasco, Peru. Dec. 27, 1899

TAYLOR, JOHN B., Railway Engineering Department, General Electric Co., Schenectady, N. Y. Mar. 27, 1903

TAYLOR, JOHN ORLO, Assistant Engineer, Colon Construction Division, Canal Zone, Panama. May 15, 1905

TAYLOR, NEIL, 58 Frederick St., Loughborough, England. Apr. 23, 1903

TAYLOR, ROBERT CAMPBELL, Superintendent Motive Power, Indiana Union Traction Co., Anderson, Ind. July 28, 1903

TAYLOR, SAMUEL NEWTON, Prof. of Elec. Engg., Western Univ. of Pennsylvania; res., 2206 Perrysville Ave., Allegheny, Pa. Dec. 18, 1903

TAYLOR, WILLIAM ARTHUR, Electrical Engineer, 241 Union St., Freeport; res., 462 Foster Ave., Chicago, Ill. Jan. 29, 1904

TAYLOR, WILLIAM BAILEY, Technical Assistant, General Electric Co.; res., 44 Hanover St., Lynn, Mass. Feb. 24, 1905

TAYLOR, WILLIAM THOMAS, Superintendent and Chief Electrician Compania Industrial Mexicana, Chihuahua, Mexico. Jan. 29, 1904

TEDFORD, HARRY ALFRED, Superintendent, Northern California R. Co., Manton, Cal. Mar. 24, 1905

TEMPLE, WORRALL E. S., Instructor in Electrical Engineering, University of Pennsylvania, Philadelphia, Pa. Oct. 23, 1903

TEN EYCK, PETER GANSEVOORT, Vice-president, Federal Railway Signal Co., Albany, N. Y. Dec. 18, 1903

TENNEY, EDGAR LAMONT, Draftsman, Indiana Steel Co.; res., 251 Montrose Boulevard, Chicago, Ill. Apr. 26, 1907

TER MEER, HENRY CHARLES, Electrical Engineer; res., 930 Hudson St., Hoboken, N. J. Feb. 28, 1901

TER MEULEN, F. W. R. VON L., Assistant Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. Apr. 22, 1904

TERRY, ALBERT SLOCOMB, Treas. and Manager, The Sunbeam Incandescent Lamp Co., 463 West St., New York City. Jan. 24, 1902

TERVEN, LEWIS AUGUSTUS, Electrician, Arthur Frantzen Co., Puerta Folsa de San Andres No. 88, Mexico City, Mex. Jan. 29, 1904

TERVET, ROBERT, Technical Engineer, Western Electric Co., North Woolwich, London, Eng. Sept. 27, 1901

TESLA, NIKOLA, Electrical Engineer and Inventor, Wardenclyffe, Long Island, N. Y. June 5, 1888

THALER, JOSEPH AUKEN [*Local Secretary*], Professor of Electrical Engineering, Montana A. & M. College, Bozeman, Mont. July 28, 1903

THAYER, BURDETT CORDALE, Westinghouse Electric and Mfg. Co., 730 Board of Trade Bldg., Boston, Mass. Apr. 26, 1907

THAYER, GEORGE LANGSTAFF, *M. E.*, Consulting Engineer, 418 Liddelle Blk., Spokane, Wash. Aug. 5, 1896

THAYER, HARRY BATES, Vice President Western Electric Co., 463 West St., New York City. Mar. 29, 1907

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THIBODEAUX, ERNEST AUGUSTUS, Superintendent, Municipal Power Plant, Donaldsonville, La. Mar. 29, 1907

THOMAS, ALFRED CLARENCE, Engineer, The New York Telephone Co., 15 Dey St., New York City. Feb. 28, 1902

THOMAS, CARROLL, Electrical Engineer, United Railways and Electric Co.; res., 1802 Guilford Ave., Baltimore, Md. Mar. 24, 1905

THOMAS, DAVID RADES, Electrical Engineer, Port Jervis Electric Co., Port Jervis, N. Y. Apr. 23, 1903

THOMAS, GEORGE CARLYLE, Engineer, Singer Mfg. Co.; res., 143 Beach St., Bridgeport, Conn. Apr. 26, 1907

THOMAS, JOHN WILLIAMS, Thomas Engineering Co., 26 North 7th St., Allentown, Pa. Mar. 22, 1901

THOMAS, LUCIAN ALVAH, Draughtsman, Westinghouse, Church, Kerr & Co.; res., 107 W. 123d St., New York City. Jan. 25, 1907

THOMAS, RICHARD HENRY, Sales Agent, White and Middleton Gas Engine Co., 107 Liberty St., New York City. Aug. 17, 1904

THOMAS, ROBERT MCKEAN, *E. E.*, Member firm of Thomas & Betts, 141 Broadway, New York City. Apr. 22, 1896

THOMAS, ROYAL DAVID, Oakmont, Pa. Mar. 1, 1907

THOMAS, STEPHEN A., Chief Electrical Inspector, Department of Education, 59th St. and Park Ave., New York City. May 17, 1904

THOMAS, WILLIAM ARTHUR, Commercial Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Dec. 15, 1905

THOMAS, W. RANDOLPH, Superintendent, Virginia Pass. and Power Co., Power House; res., 911 N. 27th St., Richmond, Va. Feb. 24, 1905

THOMPSON, ALBERT REESE, New York Edison Co., 55 Duane St.; res., 226 W. 105th St., New York City. Apr. 26, 1907

THOMPSON, ALFRED J., Electric Liquid Purifying & Filtering Co., 307 Frick Bldg., Pittsburg, Pa. Jan. 25, 1896

THOMPSON, ERMINE JOHN, 3000 Indiana Ave., Chicago, Ill. Jan. 25, 1901

THOMPSON, GEORGE LA RUE, Manager Supply Department, General Electric Co.; res., Willow Grove Road, Glenside, Pa. Apr. 28, 1905

THOMPSON, GEORGE W., Salesman, Westinghouse Electric and Mfg. Co.; res., Hazleton, Pa. July 26, 1907

THOMPSON, GUION, Litchfield, Conn. Apr. 27, 1906

THOMPSON, HARRISON GILMAN, JR., Foreman of Electricians, Waldo Ave. Yard, P. R.R., Jersey City, N. J. Feb. 27, 1903

THOMPSON, JOHN WEST, Engineering Department, Mexican General Electric Co., Mexico City, Mex. Sept. 28, 1898

THOMPSON, RALPH FOWLER, Electrical Engineer, Ivanhoe Furnace Co., Ivanhoe, Va. Apr. 23, 1903

THOMPSON, SHERMAN SIDNEY, Collins, Mo. June 14, 1905

THOMPSON, SILVANUS P., Technical College, Finsbury, Leonard St., City Road, London, E. C., Eng. Oct. 27, 1897

THOMPSON, WALTER LEE, Cameron Terrace, Woodside, L. I. Mar. 27, 1903

THOMPSON, WILBUR HAYES, Electrical Engineer, American Telephone Co., Wheeling, W. Va. Jan. 25, 1907

THOMSON, GEO. ANDROS, Special Agent, The Adams-Bagnall Electric Co., 136 Liberty St., New York City. Mar. 22, 1901

THOMSON, ROBERT RICHARDSON, Agent, General Electric Co., 1003 Majestic Bldg., Detroit, Mich. Mar. 1, 1907

THOMSON, WILLIAM HARGADINE, JR., Assistant to General Manager, St. Paul Gas Light Co., St. Paul, Minn. Mar. 1, 1907

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THOMSON, WILLIAM I., Assistant Engineer, Safety Car Heating and Lighting Co., New York City; res., Newark, N. J. Mar. 27, 1903

THORN, WRAY THOMPSON, Draftsman, Division Engineer, 10th Floor, 181 La Salle St., Chicago, Ill. Apr. 28, 1905

THORNTON, GEORGE CROSMAN, Electrical Engineer, Thornton Co., 2026 First Ave., Birmingham, Ala. June 21, 1907

THORNTON, KENNETH BUCHANAN, Asst. Operating Manager, J. G. White & Co., 43 Exchange Place, New York City. Apr. 26, 1901

THORPE, WILLIAM HORSEMAN, Sales Engineer, National Battery Co., 1606 Broadway, New York City. Sept. 22, 1905

THROCKMORTON, C. GROSS, Esmeralda Hotel, Goldfield, Nev. June 21, 1907

THURBER, HOWARD F., General Manager, New York Telephone Co., 18 Cortlandt St., New York City. Mar. 25, 1896

THURSTON, LOUIS STEWART, General Electric Co., 44 Broad St., New York City. Aug. 22, 1902

THURSTON, RALPH EMERY, Putnam Light & Power Co., Putnam, Conn. Feb. 24, 1905

TIBBALS, EMERSON C., Electrical Engineer, E. C. Tibbals & Co., 1201 Atlantic Ave., Brooklyn, N. Y. Oct. 27, 1905

TIBBS, HARRY ALBERT, Division Superintendent Southern Power Co., Great Falls, S. C. Sept. 28, 1906

TIDD, GEO. N., General Manager, Marion Light and Heating Co., Marion, Ind. July 26, 1900

TILLERY, PAUL ALLEN, Sup rintendent Washington Electrical Plant, Washington, N. C. June 19, 1903

TIMMERMAN, ARTHUR HENRY, Supt. Wagner Electric Mfg. Co., 2017 Locust St.; res., 2633 Park Ave., St. Louis, Mo. Mar. 27, 1903

TINGLEY, E. M., Westinghouse Elec. & Mfg. Co.; res., 431 Shady Ave., Pittsburg, Pa. July 12, 1900

TINGLEY, JOHN BARNES, Salesman, General Electric Co.; res., 308 Murray St., Madison, Wis. June 21, 1907

TINNEMANN, OTTO, Instructor in Electrical Engineering, Polytechnic College of Engineering, Oakland, Cal. May 14, 1906

TINSLEY, JOHN FRANCIS, Electrical Engineer, American Steel and Wire Co., Worcester, Mass. Feb. 26, 1904

TISCHNER, CHARLES FREDERICK, JR., Draftsman, Townsend & Decker, New York City; res., 397 4th St., Brooklyn, N.Y. May 19, 1903

TITLOW, EDWARD INGRAM, 1432 Geary St., San Francisco, Cal. Nov. 24, 1905

TITUS, JOSEPH VAN EMAN, Electric Service Supplies Co., 1020 Filbert St., Philadelphia Pa. Mar. 25, 1904

TITUS, SAMUEL HOWARD, with Nernst Lamp Co., 40 West 34th St., New York City; res., 7 Sherman Place, Utica, N. Y. Mar. 24, 1905

TOBEY, HARRY WILLARD, Member Engineering Dept., Stanley Elec. Mfg. Co.; res., 40 Oxford St., Pittsfield, Mass. Sept. 27, 1901

TOBEY, JESSE ORION, Superintendent, Northern California Power Co., Kennet, Cal. Apr. 22, 1904

TODD, JAMES, President, Sterling Varnish Co., Pittsburg; res., Sewickley, Pa. Jan. 27, 1905

TODD, ROBERT I., General Manager, Indianapolis Traction & Terminal Co., Indianapolis, Ind. June 15, 1904

TODD, WILLIAM NEWMAN, Assistant Electrical Engineer, Portland Co., 39 Cumberland Ave., Portland, Me. Mar. 1, 1907

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TOERRING, C. J., C. J. Toerring Co., 21st & Toronto Sts., Philadelphia, Pa. Apr. 18, 1894

TOLLE, HORACE W., General Superintendent, Mattoon City Railway, Mattoon, Ill. Oct. 27, 1905

TOLMAN, CHARLES PRESCOTT, Chief Engineer, National Lead Co., 100 William St., New York City. July 28, 1903

TOLMAN, CLARENCE M., Electrical Engineer, Bangor Ry. & Electric Co., Bangor, Me. Apr. 27, 1898

TOMLINSON, HARVEY STROUT, Tester, General Electric Co., Lynn; res., Salem, Mass. Apr. 22, 1904

TOMLINSON, L. C., Installer, Automatic Electric Co., Chicago, Ill. Mar. 29, 1907

TONKIN, JUAN, Contracting Engineer, J. G. White & Co., 43 Exchange Pl.; res., 420 W. 121st St., New York City. Mar. 1, 1907

TOPPING, ALANSON NILES, Instructor in Electrical Engineering, Purdue University, Lafayette, Ind. June 14, 1905

TORRENCE, WILLIAM WELLINGTON, Testing Department, General Electric Co.; res., 114 Victory Ave., Schenectady, N. Y. Mar. 23, 1906

TORREY, CARLETON ELI, Accountant, Tagona Water and Light Co., Saulte Ste Marie, Ont. Feb. 24, 1905

TOURET, MAXIME EUGENE JEAN, Consulting Electrical Engineer, 7 Rue Meyerbeer, Paris, France. Jan. 24, 1902

TOWER, CHARLES HOMER, Instructor, Cornell University; res., 103 Quarry St., Ithaca, N. Y. Mar. 1, 1907

TOWER, GEORGE A., V. P. Tower-Binford Electric and Mfg. Co., 7 South 7th St.; res., 715 E. Main St., Richmond, Va. May 15, 1894

TOWER, WILLIAM ARTHUR, Division Superintendent, Chesapeake and Potomac Telephone Co., Baltimore, Md. Apr. 28, 1905

TOWLE, GEORGE CARROLL, General Manager, Peoples Railway Co., Dayton, Ohio. Oct. 28, 1904

TOWN, FREDERICK E., Construction Dept., Otis Elevator Co., 17 Battery Place; res., 746 St. Nicholas Ave., New York City. May 15, 1900

TOWNE, EDWARD BARNES, Eastern Manager, Burdett-Rowntree Mfg. Co., 17 Battery Place, New York City; res., Orange, N. J. Mar. 27, 1903

TOWNSEND, ARTHUR, Electrical Engineer, Townsend & Hutt, Milestone Sask, Canada. Oct. 27, 1905

TOWNSEND, HENRY C., Attorney and Expert in Electrical Cases, 141 Broadway; res., 354 W. 123d St., New York City. July 10, 1888

TOZER, CHARLES ADELBERT, Telluride Power Co., Ames, Colo. Apr. 26, 1907

TRACY, ATLEE HOFFMAN, Electrical Engineer, with George Gibbs, 10 Bridge St., New York City. Feb. 23, 1906

TRACY, FRED GLYNDON, Manager, C. G. Tracy & Co., Glyndon, Minn. July 19, 1904

TRAFFORD, BERNARD WALTON, General Manager, Chesapeake and Potomac Telephone Co., Washington, D. C. Mar. 29, 1907

TRAVERS, HENRY ADELBERT, Engineering Apprentice, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Nov. 24, 1905

TRAWICK, SAMUEL WILKINS, Agent Railway Department, General Electric Co., 44 Broad St., New York City. Mar. 1, 1907

TRAVIS, THURLOW, Electrical Foreman, N.Y. C. & H. R. R.R., Port Morris Power House, 142d St. & E. R., New York City. July 26, 1907

TREADWAY, WILLIAM ANDREW, 2215 La. St., Little Rock, Ark. Dec. 19, 1902

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TREAT, ROBERT BELDEN, Electrical Engineer, Crocker-Wheeler Co., Ampere; res., 70 North 5th St., Newark, N. J. Jan. 3, 1902

TREEBY, W. VINCENT, Electrical Engineer, Crompton & Co., Ltd., Salisbury House, London Wall, London, E. C., Eng. June 15, 1904

TRIPIER, HENRI, Technical Engineer of the Societé Francaise d'Incandescence par le Gaz (Systeme Auer.), Paris, France. Sept. 28, 1898

TRIPP, CHARLES A., Partner, McMeans & Tripp, 607 State Life Bldg., Indianapolis, Ind. Mar. 1, 1907

TRIPP, GEORGE MASON, Assistant Superintendent, British Columbia Electric Railway Co., Victoria, B. C. Dec. 19, 1902

TRITLE, JOHN FRANKLIN, Tester, General Electric Co.; res., 838 Union St., Schenectady, N. Y. Sept. 28, 1906

TROUT, PHILIP HENRY, JR., Electrical Engineer, Staunton, Va. Aug. 17, 1904

TROW, HARRIS CUSHMAN, Instructor of E. E., American School of Correspondence, Armour Institute of Tech., Chicago, Ill. Feb. 26, 1904

TROY, DANIEL W., Electrical Expert, Stewart & Stewart, 60 Wall St.; res., 111 W. 104th St., New York City. Mar. 1, 1907

TRUESDELL, ARTHUR E., 50 Brenton Terrace, Pittsfield, Mass. Feb. 15, 1899

TSCHENTSCHER, RUDOLPH, Electrical Engineer, Illinois Steel Co., South Chicago, Ill. Dec. 15, 1905

TSUKAMOTO, CHUZABURO, Power & Mining Engg., General Electric Co.; res., 406 Summit Ave., Schenectady, N. Y. Apr. 22, 1904

TUCKER, FRANK STEVENSON, Engineer, Westinghouse Electric & Mfg. Co., 605 Trust Bldg., Charlotte, N. C. June 21, 1907

TUDELA, GABRIEL, 88 Valladolid St., Lima, Peru. Sept. 28, 1906

TUNE, ROSCOE I.,Conduit Inspector, Chesapeake & Potomac Telephone Co.; res., 921 F St., N. E., Washington, D. C. Sept. 28 1906

TURBAYNE, WILLIAM ARTHUR, Electrical Engineer, Gould Coupler Co., Lancaster, N. Y. Feb. 26, 1904

TURNBULL, FREDERICK CHARLES, North California Power Co., Fern, Cal. June 14, 1905

TURNBULL, ROBERT THORBURN, *M. I. E. E.*, Turnbull & Jones, Ltd. Wellington, N. Z. Jan. 26, 1906

TURNER, HARRY WINTHROP, Consulting Engineer Oswaldestre House, Norfolk St., London, W. C., Eng. Nov. 20, 1903

TURNER, MATHIAS EVERETT, Electrical Engineer, Cleveland Electric Illuminating Co., 711 Cuyahoga Bldg., Cleveland, O. Feb. 27, 1903

TURPIN, MANLY CURRY, Superintendent Light, Heat & Power Co., Auburn, N. Y. May 19, 1903

TUTTLE, ELBERT BARRETT, Electrical Engineer, Central District & Printing Telegraph Co., Pittsburg, Pa. Sept. 28, 1906

TUTTLE, HORACE BURT, Engineering Chemist, 727 Cuyahoga Building, Cleveland, O. Sept. 26, 1902

TWINING, WILLIAM STANTON, Chief Engineer, Philadelphia Rapid Transit Co.; res., 160 Coulter St., Philadelphia, Pa. Sept. 22, 1905

TYLER, ALVA WARREN, Designing Engineer, United States Gypsum Co., Oakfield, N. Y. Mar. 29, 1907

TYLER, VICTOR MORRIS, Secretary, The Southern New England Telephone Co., New Haven, Conn. Apr. 23, 1903

UHDEN, CARL F., Chief Draughtsman, Washington Water Power Co., 908 Cora Ave., Spokane, Wash. Oct. 27, 1905

UHL, ALBERT, 1149 Madison Ave., Memphis, Tenn. Apr. 23. 1903

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UNDERHILL, CHARLES REGINALD, Consulting Electrical Engineer, 55 Liberty St., New York City. Sept. 25, 1903

UNDERWOOD, CHARLES W., Manager, Westinghouse E. & M. Co., 780 Ellicott Sq.; res., 43 Norwood Ave., Buffalo, N. Y. Feb. 26, 1904

UNDERWOOD, LOUIS EDWARD, Designing Engineer, General Electric Co., West Lynn, Mass. Apr. 23, 1903

UPP, JOHN W., Engineer in Charge Draughting Room, General Electric Co., res., 27 Wendell Ave., Schenectady, N. Y. Mar. 27, 1903

UPTEGRAFF, WALTER DENNY, Second Vice-president and Treasurer, Nernst LampCo., Westinghouse Bldg., Pittsburg, Pa. Dec. 28, 1906

URBAN, HENRY, Engineer, Societe Generale de Chemins de Fer Economiques, 26 Rue Gachard, Brussels, Belgium. Dec. 28, 1906

URQUHART, ROBERT FRAZIER, Assistant Installing Engineer, Northern California Power Co., Manton, Cal. Mar. 29, 1907

USHER, GEORGE H., General Superintendent, Postal Telegraph Cable Co., Prudential Bldg., Atlanta, Ga. Sept. 28, 1906

UZZELL, GEORGE WALTER, 1713 No. River Ave., Spokane, Wash. Apr. 26, 1907

VAIL, LEWIS HERBERT, Assistant to Electrical Engineer, D. L. and W. Railway Co.; res., 1628 Vine St., Scranton, Pa. Apr. 27, 1906

VAIL, THEO. N., 26 Cortlandt St., New York City. Apr. 15, 1884

VAIL, WILLIAM H., Erecting Engineer, United Railways and Electric Co., of Baltimore; res., Ruxton, Baltimore, Md. Feb. 24, 1905

VAILL, CHARLES PARTRIDGE, Assistant Superintendent, Electrical Cable Works, American Steel and Wire Co., Worcester, Mass. Apr. 27, 1906

VALENTINE, FREDERICK PALMER, Engineer of Traffic, N. E. Telephone and Telegraph Co., 101 Milk St., Boston, Mass. Apr. 26, 1907

VALENTINE, WALTER SCOTT, Asst. Engr., Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. Jan. 23, 1903

VALLADARES, ANTENOR, Electrical Engineer, Lima, Peru. Apr. 27, 1906

VANATTA, FRANK TULLER, Chief Electrician, North Shore R.R. Co., Sausalito; res., 24 De Long Ave., San Francisco, Cal. June 14, 1905

VAN ATTA, ROY EDWIN, Kansas City Southern Ry., Kansas City, Mo. Dec. 15, 1905

VAN BUREN, GURDON C., Supt. of Power, Hudson River Telephone Co.; res., 76 Clinton Ave., Albany, N. Y. Oct. 25, 1892

VANCE, CLAUDE EDWARD, Assistant Engineer, British Electric Traction Co., Ltd., Norfolk St., London, W. C., England. Mar. 29, 1907

VANCE, J. H., Mechanical Engineer, B. F. Goodrich Co.; res., 402 Crosby St., Akron, Ohio. Mar. 27, 1903

VAN CLEEF, ELLICOTT EARL, Assistant to Supt. of Construction, Western Electric Co., 463 West St., New York City. Mar. 27, 1903

VAN COTT, LINCOLN, Purchasing Agent, Brooklyn Heights R.R. Co., 85 Clinton St., Brooklyn, N. Y. July 19, 1904

VAN DEINSE, ANTON FAY, 454 N. Marengo Ave., Pasadena, Cal. May 15, 1905

VANDERBILT, LEROY BROWNLEE, Assistant, Electrical Department, B. & O. R.R., Baltimore, Md. Sept. 28, 1906

VAN DYCK, WILLIAM VAN BERGEN, Electrical Engineer, W. R. Grace & Co., Valparaiso, Chili, S. A. Nov. 22, 1901

VAN ETTEN, HERBERT BRIANT, Assistant Engineer, New York Telephone Co., 15 Dey St., New York City. Apr. 22, 1904

VAN GELDER, HOWARD MASON, Electrical Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. Apr. 28, 1905

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VANKIRK, EDWARD POWER, Electrical Engineer, Elizabeth, Pa. Jan. 3, 1902

VAN NESS, LEONARD G., 22 North 2d St., Memphis, Tenn. Jan. 29, 1904

VAN NORDEN, RUDOLPH WARNER, Consulting Engineer, 912 Mutual Savings Bank Building, San Francisco, Cal. Feb. 27, 1903

VAN RIPER, WILLIAM R., Foreman of Substation, N. Y. C. & H. R. R. R., 198th Street and Webster Ave., Bronx, N. Y. June 21, 1907

VAN SLYCK, C. H., Salesman, General Electric Co., 44 Broad St.; res., 80 Washington Square, E., New York City. Mar. 27, 1903

VAN SLYKE, FREDERICK EDGAR, Engineer, Jeffrey Mfg. Co., Columbus, O. Jan. 29, 1904

VAN VALKENBURG, ASA T., Erecting Engineer, Westinghouse Machine Co., 171 La Salle St., Chicago, Ill. Dec. 28, 1906

VAN VALKENBURG, HERMON LEACH, Chief Engineer, Walker Electric Co., Noble & 23d Sts., Philadelphia, Pa. May 15, 1905

VAN VLEET, ROY MITCHELL, Manager, Cutler-Hammer Mfg. Co., 1232 Monadnock Bldg., Chicago, Ill. Mar. 22, 1901

VAN WAGENEN, EDWARD, Assistant Electrical Engineer, Gould Storage Battery Co., 341 Fifth Ave., New York City. Sept. 28, 1906

VAN WART, THEODORE, J. W. Foreman Electrical Department, Reid Newfoundland Co., St. Johns, N. F. Mar. 23, 1906

VAN WEELDEN, HAROLD C., Sales Department, General Electric Co., 44 Broad St., New York City. Mar. 29, 1907

VAN WYCK, JAMES R., Draftsman, F. S. Pearson, 25 Broad St., New York City; res., 45 Pulaski St., Brooklyn, N. Y. Nov. 24, 1905

VAN WYCK, PHILIP V. R., JR., Empire City Subway Co., 426 W. 58th St., New York City; res., Plainfield, N. J. Apr. 21, 1891

VARNEY, FRANK H., Electrician, San Francisco Gas and Electric Co., 2912 Mission St., San Francisco, Cal. July 26, 1900

VARNEY, THEODORE [*Local Secretary*], Elec. Engineer, Westinghouse Electric & Mfg. Co.; res., 5719 Howe St., Pittsburg, Pa. Apr. 28, 1905

VARNEY, WILLIAM WESLEY, Mechanical Engineer, 1209 Calvert Bldg.; res., 710 N. Carey St., Baltimore, Md. Nov. 21, 1894

VASSAR, HERVEY SACKETT, Draughtsman, Engineering Department, P. S. C. of N. J.; 207 Market St., Newark, N. J. Mar. 23, 1906

VAUGHAN, JOHN FAIRCHILD, Engineer, Stone & Webster Engineering Corporation, 147 State St., Boston, Mass. Feb. 27, 1903

VAUGHAN, RICHARD, Engineer, Seattle Electric Co., 907 First Ave., Seattle, Wash. May 15, 1905

VAWTER, CHARLES ERASTUS, JR., Professor of Physics, Virginia Polytechnic Institute, Blacksburg, Va. June 21, 1907

VELARDE, MANUEL CARLOS, Villata 62a, Lima, Peru. Nov. 24, 1905

VENABLE, WM. MAYO, General Manager, Sanitary Engineering Co., 237 Broadway, New York City. Nov. 30, 1897

VER PLANCK, WILLIAM EVERETT, Assistant Engineer, General Electric Co., Lynn, Mass. July 19, 1904

VESER, LUCIUS OTTO, West Penn. Railway Co., Connellsville, Pa. Dec. 19, 1902

VIALL, BENJAMIN THOMAS, Construction Engineer, 719 N. Soto St., Los Angeles, Cal. July 28, 1903

VICKERS, FREDERICK ELWOOD, Expert, General Electric Co., Union Trust Building, San Francisco, Cal. Apr. 22, 1904

VIEHE, J. S., Electrical Engineer, Federal Construction Co., Rockingham, N. C. May 15, 1900

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VINAL, ALBERT CARLETON, American Telegraph and Telephone Co., 15 Dey St., New York City. Feb. 26, 1904

VINCENT, HAROLD BLANCHARD, Chief Operator, Niagara, Lockport and Ontario Power Co., Lockport, N. Y. Jan. 27, 1905

VINCENT, JAY CARTER, Engineering Staff, Twin City Rapid Transit Co.; res., 1313 6th St., S. E., Minneapolis, Minn. Oct. 27, 1905

VINCENT, WILLIAM GERMAIN, JR., Draftsman, Ocean Shore Railway Co., 54 Eleventh St., San Francisco, Cal. Dec. 15, 1905

VINTEN, ERNEST STILES, Foreman Knob Dept., Sargent Co.; res., 89 Pearl St., New Haven, Conn. Apr. 27, 1898

VISSCHER, OSWALD WILLIAM, Engineering Salesman, Western Electric Co., 11th and York Sts., Philadelphia, Pa. Mar. 1, 1907

VOIT, DR. ERNST., Professor of Electricity, Technical University, Schwanthalerstrasse, Munchen, Germany. Mar. 21, 1894

VOLK, JOSEPH A., JR., Treasurer and Superintendent, Reed & Volk Electrical Co., So. Norwalk, Conn. Sept. 28, 1906

VOM BAUR, CARL HANS, Electrical Engineer, 152 Pleasant St., Arlington, Mass. Sept. 26, 1902

VON AMMON, SIEGFRIED, Consulting Engineer, Br. W. E. & M. Co., Ltd., Bowden near Manchester, Eng. Apr. 23, 1903

VON DANNENBERG, CARL OTTO, Electrician in charge, Dept. of Construction, Pensacola Navy Yard, Warrington, Fla. Dec. 28, 1906

VON LEHOCZKY, PAUL, Assistant Electrical Engineer, Allegheny County Light Co., Pittsburg, Pa. Mar. 1, 1907

VON ZWEIGBERGK, THORSTEN, Electrical Engineer, Dick, Kerr and Co., Ltd., Preston, Eng. Aug. 17, 1904

VREELAND, FREDERICK K., 80th St. and East End Ave., New York City. Oct. 26, 1898

WADDELL, CHARLES EDWARD, Electrician in charge Electrical Dept., Biltmore Estate, Biltmore, N. C. Apr. 25, 1902

WAGGAMAN, HENRY ELLIOT, 1321 F St., N. W., Washington, D. C. Jan. 27, 1905

WAGONER, PHILIP DAKIN, Commercial Department, General Electric Co., Schenectady, N. Y. Feb. 28, 1902

WAGNER, JEAN ROBERT, Foreman Meter Department, New York Edison Co.; res., 238 E. 124th St., New York City. Mar. 1, 1907

WAGNER, WALTER CALVIN, Instructor and Student, University of Washington; res., 6000 Corliss Ave., Seattle, Wash. Dec. 28, 1906

WAITT, ARTHUR MANNING, Consulting Engineer, Room 916, 320 Fifth Ave., New York City. June 19, 1903

WAKEMAN, JAMES MEANLEY, Manager, *Electrical World and Engineer*, 239 W. 39th St., New York City. Feb. 27, 1903

WALBORN, IRA GUY, Utah Independent Telephone Co., Salt Lake City, Utah. Nov. 25, 1904

WALBRAN, CHRISTOPHER JAMES, JR., Manager, 252 Equitable Building Denver, Col. Nov. 24, 1905

WALDRON, LOUIS D., Salesman, Allis-Chalmers Co., 222 Ellicott Square, Buffalo, N. Y. June 1, 1907

WALDO, EDWARD HARDENBERGH, Assistant Professor of Electrical Engineering, University of Illinois, Urbana, Ill. Jan. 25, 1907

WALES, SAMUEL SIGOURNEY, Electrical Engineer, Homestead Steel Wks., Munhall, Pa. July 19, 1904

WALKEM, GEORGE ALEXANDER, Electrical and Mechanical Engineer, Vancouver, B. C. Nov. 23, 1900

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WALKER, EWART BUCHAN, Storage Battery Engineer, Canadian General Electric Co., Ltd., 14 King St., E., Toronto, Ont. Jan. 29, 1904

WALKER, FERNANDO MURRAY, Manager, R. E. Briggs & Co., Mexico City, Mex. Sept. 28, 1906

WALKER, FREDERICK WILEY, Vice-President and Chief Engineer, Comstock-Haigh-Walker Co., Port Washington, Wis. Nov. 24, 1905

WALKER, MILES, Electrical Engineer, The British Westinghouse Electric and Mfg. Co., Ltd., Manchester, Eng. Sept. 27, 1901

WALKER, WILLIAM J., Electrician, Navy Yard; res., 290 Clinton Ave., Brooklyn, N. Y. Apr. 28, 1905

WALL, BENJAMIN, Metropolitan Engineering Co., 124 W. 42d St., New York City; res., 477 Bergen St., Brooklyn, N. Y. Sept. 28, 1906

WALL, WILLIAM GUY, Chief Engineer, National Motor and Vehicle Co., Indianapolis, Ind. June 21, 1907

WALLACE, CHAS. F., Engineer, Stone & Webster Engineering Corporation, 84 State St., Boston; res., Wellesley Hills, Mass. Nov. 18, 1896

WALLACE, ERNEST LEROY, Instructor Electrical Engineering, Amer. School of Correspondence, 3209 State St., Chicago, Ill. Oct. 26, 1906

WALLACE, J. EUGENE, Electrical Engineer, 1 Nassau St., New York City. May 17, 1904

WALLACE, JOHN FINDLEY, Chairman, Board of Directors, Westinghouse, Church, Kerr & Co., 111 Broadway, New York City. Jan. 25, 1907

WALLACE, ROSS STRAWN, Supt. Peoria Gas and Elec. Co., 125 N. Jefferson Ave., Peoria, Ill. Jan. 23, 1903

WALLACE, WILLIAM MURRAY, Electrical Draftsman, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City. Jan. 25, 1907

WALLAU, HERMAN L., Assistant Electrician, Cleveland Elec. Ill. Co., 711 The Cuyahoga, Cleveland, Ohio. May 15, 1900

WALLER, CHAS. WAITE, California Electric Corporation, Shreve Bldg., San Francisco, Cal. Aug. 23, 1899

WALLER, EDMUND PUTZEI, Electrical Engineer, General Electric Co., res., 14 Union St., Schenectady, N. Y. Mar. 27, 1903

WALLS, JOHN ABBET, Assistant Engineer, Shawinigan Water and Power Co., 85 Bank of Ottawa Bldg., Montreal, P. Q. May 19, 1903

WALMSLEY, WALTER NEWBOLD, Sao Paulo Tramway Light & Power Co., Ltd., Sao Paulo, Brazil. Oct. 24, 1900

WALSH, JAMES, Assistant Foreman, Meter Department, General Electric Co.,; res., 624 Western, Lynn, Mass. May 19, 1903

WALTER, HARRY CASPER, Administrator of J. Walter, Jr., and Catherine B. Schafer, 1127 13th St., N. W., Washington, D. C. Nov. 28, 1903

WALTER, JOHN CHARLES, Ford, Bacon & Davis, Memphis, Tenn. Nov. 24, 1905

WALTON, PERCY JAMES, Switchboard Inspector, General Electric Co., Philadelphia, Pa. Apr. 26, 1907

WARD, CHARLES ARCHIBALD, 172 Lexington Ave., Pittsburg, Pa. Apr. 23, 1903

WARDER, JOHN HAINES, Secretary, Western Society of Engineers, 1737 Monadnock Building, Chicago, Ill. June 21, 1907

WARDER, WALTER JAMES, JR., Designing Electric Engineer, Roth Bros. & Co., 27 S. Clinton St., Chicago, Ill. Apr. 23, 1903

WARING, J. M. S., Engineer, Electric Storage Battery Co., 1425 Marquette Bldg., Chicago, Ill. Sept. 28, 1906

WARING, TRACY DICKEY, Superintendent, Standard Underground Cable Co., Perth Amboy, N. J. Nov. 23, 1906

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WARMAN, FREDERICK CONOVER, U. S. Engineer, 1000 22d St., N. W., Washington, D. C. Apr. 28, 1905

WARNER, ARTHUR P., Northern Electric Mfg. Co.; res., 4339 Berkeley Ave., Chicago, Ill. Sept. 25, 1903

WARNER, CHARLES EMORY, Rossiter, McGovern & Co., 84 State St., Boston, Mass. Aug. 17, 1904

WARNER, CHARLES H., Electrical Engineer, Fall River, Mass. Dec. 20, 1893

WARNER, CHAUNCEY DIXON, Electrical Engineer, Moore Electrical Co., 52 Lawrence St., Newark. June 14, 1905

WARNER, RICHARD FRANCHOT, Electrical Engineer, Schenectady Illuminating Co.; Schenectady, N. Y. Jan. 23, 1903

WARREN, ALDRED KENNEDY, Chief Engineer, American Automatic Signal Co., 65 N. J. Railroad Ave., Newark, N. J. Nov. 20, 1895

WARREN, EDWARD GEORGE, Managing Director, Greenwood Electric Co., Ltd., Greenwood, B. C. Jan. 26, 1906

WARREN, FREDERIC AUSTIN, General Electrician, Fuel Department, Colorado Fuel and Iron Co., Canon City, Colo. June 19, 1903

WARREN, HALBERT B., Chief Engineer, Warren Electric Mfg. Co., Sandusky, Ohio. July 19, 1904

WARREN, HARRY MUNSON, Electrical Engineer, The Coal Mining Dept., D. L. & W. Railway Co., Scranton, Pa. Mar. 27, 1903

WARREN, HENRY ELLIS, Assistant Engineer, The Lombard-Governor Co., Ashland; res., Newton Centre, Mass. Jan. 24, 1902

WARREN, HOWARD SAUNDERS, Electrical Engineer, American Telephone and Telegraph Co., 15 Dey St., New York City. Mar. 27, 1903

WARREN, JOHN FRANCIS, Electrician, Noyes Bros., Dunedin, N. Z. Apr. 27, 1906

WARREN, WILLIAM APPLETON, President and General Manager, Simplex Co., Newark, N. J. Sept. 28, 1906

WARREN, WILLIAM HENRY, Electrical Engineer, Sprague Electric Co., 527 W. 34th St., New York City. Feb. 27, 1903

WASON, CHAS. W., President and Manager, Cleveland, Painesville and Eastern R.R., 616 Garfield Bldg., Cleveland, Ohio. May 19, 1891

WATANABE, KOGORO, Electrical Engineer, Mitsui & Co., Tokyo, Japan. Aug. 25, 1905

WATANABE, NOBLE, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 29, 1907

WATERMAN, MARCUS B,. Assistant Electrician, United Telpherage Co., Westfield, N. J. Feb. 15, 1896

WATERS, EDWARD G., General Electric Co.; res., 910 Union St., Schenectady, N. Y. Mar. 18, 1890

WATERS, HENRY LANGWORTHY, Assistant Electrical Engineer, Central District and Printing Telegraph Co., Pittsburg, Pa. Mar. 1, 1907

WATERS, HERMAN BIERCE, Instructor, California Polytechnic School, San Luis Obispo, Cal. Oct. 28, 1904

WATERSON, KARL WILLIAM, Engineering Department, American Tel. and Tel. Co., 15 Dey St., New York City. Apr. 28, 1905

WATJEN, HERMAN OTTO, Assistant Engineer, Stanley G. I. Mfg. Co.; res., 33 Henry Ave., Pittsfield, Mass. Nov. 24, 1905

WATKINS, FREDERICK ARTHUR, Western Electric Co., 463 West St.; res., 31 West 82d St., New York City. Mar. 23, 1906

WATMOUGH, PENDLETON G., JR., Electrical Engineer, 1 Broadway, New York City; res., 32 Stuyvesant Pl., S. I., N. Y. Dec. 18, 1903

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WATROUS, CLEVELAND ELMER, Manager, Cutler Hammer Mfg. Co., 136 Liberty St., New York City. June 21, 1907

WATSON, ARTHUR EUGENE, Assistant Professor of Physics, Brown University, Providence, R. I. July 28, 1903

WATSON, DANIEL BREWSTER, Draughtsman, Emerson Electric Mfg. Co.; res., 2307 Locust St., St. Louis, Mo. Jan. 26. 1906

WATSON, GEORGE GAYLORD, Electrical Engineer, Westinghouse Elec. & Mfg. Co., Pittsburg, Pa. Sept. 28, 1906

WATSON, GEORGE HATHON, Watson Flagg & Co., 27 Thames St., New York City; res., 184 Carroll St., Paterson, N. J. Feb. 27, 1903

WATSON, KENNETH, Electrical Engineer, 9a Hankow, Shangai, China. May 19, 1903

WATSON, RICHARD CARR, Assistant Regulator, New York Edison Co.; New York City. June 15, 1904

WATT, GEORGE YOUNG, Student, Brooklyn Polytechnic Institute; res., 22 Stuyvesant Ave., Brooklyn, N. Y. Jan. 25, 1907

WATTS, FRANK WILMER, Salesman, Westinghouse Electric & Mfg. Co., Hazleton, Pa. Jan. 27, 1905

WATTS, GEORGE W., Assistant to General Manager, Canadian General Electric Co., Ltd., 16 E. King St., Toronto, Ont. Feb. 26, 1904

WATTSON, ALONZO SABINE, Electrical Engineer, Rio de Janeiro Tramway Light & Power Co., Rio Janeiro, Brazil. Dec. 19, 1902

WAUGH, JOHN HAROLD, Ft. Pitt Electric Supply Co., 341 Second Ave., Pittsburg, Pa. Jan. 26, 1906

WAXBOM, CARL JOHAN EVALD, Electrical Engineer, Jeffrey Mfg. Co., Columbus; res., Westerville, O. Feb. 26, 1904

WAY, SYLVESTER BEDELL, Superintendent Union Electric Light and Power Co., 4864 Fountain Ave., St. Louis, Mo. Sept. 25, 1903

WAYNE, JACOB LLOYD, 3d, Division Equipment Foreman, Central Union Telephone Co., 35 W. Ohio St., Indianapolis, Ind. Jan. 23, 1903

WEAVER, AMOS SHELDON, Student, General Electric Co., 44 Broad St.; New York City. June 15, 1904

WEAVER, MAURICE EDGAR, Student, Massachusetts Institute of Technology, Boston, Mass. June 14, 1905

WEBB, HENRY STORRS, International Correspondence Schools; res., 1416
[Life Member] Monsey Ave., Scranton, Pa. Nov. 20, 1895

WEBER, FREDERICK CARL, Engineering Dept., Chicago, Telephone Co., Chicago, Ill. May 17, 1904

WEBER, WILLIAM F., Electrical Operator, Interborough Rapid Transit Co., 173 Spring St., New York City. Feb. 23, 1906

WEBSTER, CHARLES CARLTON, Chief Engineer Pumping Station, Department of Public Works, Schenectady, N. Y. Jan. 25, 1907

WEBSTER, DWIGHT EDWARD, Engineer, Westinghouse E. & M. Co., 1420 New York Life Bldg., Chicago, Ill. Apr. 23, 1903

WEBSTER, JOHN ENOCH, General Engineer, Westinghouse Electric & Mfg. Co.; res., 7927 Tacoma St., Pittsburg, Pa. June 21, 1907

WEBSTER, WALTER COATES, Asst. to 2d Vice-president, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City. Jan. 3, 1902

WEED, JAMES MURRAY, Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. June 21, 1907

WEHRLEY, EDWARD JUSTUS, Special Agent, American Tel. and Tel. Co., 15 Dey St., New York City; res., East Orange, N. J. June 15, 1904

WEICHSEL, HANS, Draftsman, Electrical Engineer, Wagner Electric Co., St. Louis, Mo. Dec. 15, 1905

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WEIDMAN, VICTOR NUGENT, Switchboard Draughtsman, Westinghouse E. & M. Co., Pittsburg, Pa. June 15, 1904

WELCKE, CELESTIN JOHN, Operating Department, Electric Storage Battery Co., 100 Broadway, New York City. Aug. 22, 1902

WELLES, FRANCIS R., Manufacturer, 46 Avenue de Breteuil, Paris, France. Sept. 6, 1887

WELLMAN, HARLAN PAGE, Superintendent Motive Power, Camden Interstate Railway Co., Ashland, Ky. Mar. 25, 1904

WELLMAN, SAMUEL THOMAS, President, The Wellman-Seaver-Morgan Engineering Co., New England Bldg., Cleveland, O. Jan. 23, 1903

WELLS, ARTHUR EDWIN, Consulting Engineer, 32 Liberty St.; res., 718 St. Nicholas Ave., New York City. May 19, 1903

WELLS, GEORGE EUGENE, Consulting Electrical Engineer, Ruebel & Wells. 303 Chemical Building, St. Louis, Mo. Sept. 27, 1901

WELLS, JOHN ALLEN, Chief Engineer, Augusta-Aiken Railway & Electric Co., Augusta, Ga. Apr. 23, 1903

WELLS, WALTER FARRINGTON, Edison Electric Illuminating Co., 360 Pearl St., Brooklyn, N. Y. Apr. 26, 1899

WELSH, JAMES WINFIELD, Assistant Electrician, Pittsburg Railways Co.; res., 120 Oakview Ave., Edgewood Park, Pa. Mar. 1, 1907

WELZ, FRANK, Electrical Engineer, Guadalajara, Mex. Jan. 23, 1903

WENDT, SAMUEL J., Draughtsman, North Shore Electric Co., Highland Park, Ill. Sept. 28, 1906

WENGER, EDGAR I., University of Illinois, Urbana, Ill. May 21, 1901

WENNER, FRANK, Bureau of Standards, Washington, D. C. Apr. 28, 1905

WENTZ, ROBERT FILMORE, Mechanical Designing and Construction Engineer, 508 Hammond Bldg., Detroit, Mich. Apr. 23, 1903

WERNER, GERARD BERNARD, Railway Electric Power Co., 114 Liberty St., New York City. Apr. 28, 1905

WERTH, MATTHEW FOUTAINE MAURY, Superintendent of Construction, Witherbee Igniter Co., 541 W. 43d St., New York City. Aug. 17, 1904

WESSELHOEFT, CHARLES DIETRICH, Electrical Engineer, Kohler Brothers; res., 749 So. Sawyer Ave., Chicago, Ill. Sept. 25, 1903

WESSLING, ALBERT GUSTAVE, Asst. Engineer, Bullock Electric Mfg. Co.; res., 549 Milton St., Cincinnati, Ohio. Feb. 27, 1903

WEST, ERASTUS LOVETTE, Asst. to Electrical Engineer, J. G. White & Co., 43 Exchange Pl., New York City. Apr. 25, 1902

WEST, JULIUS HENRIK, Consulting Engineer, 21 Am Karlsbad, Berlin, W. 35, Germany. Sept. 20, 1893

WESTBROOKE, FRANCIS ABEKEN, Electrician, New York and New Jersey Telephone Co., Brooklyn, N. Y. Mar. 1, 1907

WESTBURG, PAUL AUGUSTUS, Secretary and Electrical Engineer, F. B. Badt and Co., 1504 Monadnock Block, Chicago, Ill. June 21, 1907

WESTERVELT, ANDREW, Superintendent Electrical Department, Howard E. Crook & Co., 301 N. Howard St., Baltimore, Md. Feb. 23, 1906

WESTINGHOUSE, GEORGE, President, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. May 20, 1902

WESTON, SYDNEY F., Phoenix Fire Extinguisher Co., 44 E. 23d St., New York City. July 12, 1900

WETZLER, JEFFERSON, Secretary and Treasurer, Electrical Engineer Institute, 240 West 23d St., New York City. July 25, 1902

WEYMOUTH, THOMAS ROTE, Engineer, National Transit Co., 206 Seneca St., Oil City; res., Lock Haven, Pa. Nov. 22, 1901

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WHARFF, EDWARD MANSFIELD, Apprentice, Rochester, Syracuse and Eastern R.R.; res., 15 High St., Newark, N. Y. Dec. 28, 1906

WHEELER, ARTHUR SOMES, Washington Insurance Association, Tolman Bldg., Seattle, Wash. Apr. 28, 1905

WHEELER, BURR, Cos Cob, Conn. Apr. 22, 1904

WHEELER, EARL, Instructor in Electrical Engineering, Engineering School, Washington Barracks, D. C. Feb. 23, 1906

WHEELER, LEONARD ELLWOOD, Superintendent of Meter Department, Maryland Electric Co., Baltimore, Md. Apr. 28, 1905

WHEELER, WALTER SCOTT [*Local Secretary*], 3120 East Union St., Seattle, Wash. Sept. 25, 1903

WHIPPLE, CYRUS AVERY, Bremerton, Wash. June 19, 1903

WHISLER, BENJAMIN ARTHUR, Electrician, Hudson River Electric Power Co.; res., 20 Linwood Place, Utica, N. Y. Sept. 28, 1906

WHITAKER, JOHN SANBORN, Superintendent, Rockingham County Light and Power Co., Portsmouth, N. H. Apr. 23, 1903

WHITAKER, S. EDGAR, Office Manager, American Society of Mechanical Engineers, 29 W. 39th St., New York City. Aug. 5, 1896

WHITAKER, WILLIAM GORDON HOWARD, JR., N. Y. Telephone Co., 15 Dey St., New York City. May 15, 1905

WHITE, EDWARD P., Superintendent, Asheville Electric Co., 99 Woodfin St., Asheville, N. C. July 28, 1905

WHITE, ERNEST CANTELO, Illuminating Engineer, Winnipeg, Can. Oct. 26, 1906

WHITE, FRANCIS JOSEPH, Engineer, Electrical Department., N. Y. C. & H. R. R.R. Co., New York City, Apr. 25, 1902

WHITE, HAROLD E., Designing Engineer, General Electric Co., res.; 27 Parkwood Boulevard, Schenectady, N. Y. Apr. 23, 1903

WHITE, HENRY STEVENS, Assistant Superintendent, Greenville Carolina Power Co., Greenville, S. C. Apr. 26, 1907

WHITE, J. WILLIAM, Superintendent, Nevada-California Power Co., Goldfield, Nev. Aug. 17, 1904

WHITE, LINDEN G., Superintendent Electrical Department, Columbus Railway and Light Co., Columbus, Ohio. Mar. 28, 1902

WHITE, PAUL HELB, Sec'y and Treasurer, Animas Power and Water Co., Newton-Claypool Building, Indianapolis, Ind. Jan. 26, 1906

WHITE, RICHARD ALBERT, Assistant Engineer, Ford, Bacon & Davis, 115 Broadway, New York City. June 19, 1903

WHITE, WILLIAM DEXTER, Water Wheel Governor Department, Holyoke Machine Co., Worcester, Mass. Apr. 27, 1906

WHITE, WILLIAM WESLEY, Assistant Mechanical Engineer, Crown Cork & Seal Co., Baltimore, M. D. Apr. 23, 1903

WHITEHEAD, JOHN B., JR., Associate in Applied Electricity, Johns Hopkins University, Baltimore, Md. Oct. 24, 1900

WHITEHEAD, JOHN ROY, Assistant Electrical Engineer, U.S. Signal Corps, Washington, D. C. May 15, 1905

WHITELEY, RAYMOND, 26 Garden St., Todmorden, York, Eng. Oct. 28, 1904

WHITESIDE, ADDISON HAGES, District Manager, Allis-Chalmers Co., Land Title Bldg., Philadelphia, Pa. May 15, 1905

WHITESIDE, WALTER HUNTER, President Allis-Chalmers Co., Milwaukee, Wis. Jan. 24, 1902

WHITING, ALLEN H., Automobile Engineer, 1776 Broadway, New York City. Nov. 18, 1896

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WHITING, MAX ALBERT, Power and Mining Department, General Electric Co.; res., 4 Eagle St., Schenectady, N. Y. Apr. 26, 1907

WHITING, S. E., Instructor in Electrical Engineering, Harvard University; res., 11 Ware St., Cambridge, Mass. May 16, 1899

WHITMORE, W. G., Electrical Engineer, General Electric Co., Edison Building, New York City. Mar. 18, 1890

WHITNEY, EDDY RUSSEL, Engineer, Commercial Truck Co., Philadelphia, Pa. May 19, 1903

WHITNEY, FRANK E., Assistant General Manager, Auto Transit Co., Arcade Building, Philadelphia, Pa. Oct. 27, 1905

WHITNEY, GILBERT C., Signal Draftsman, General Railway Signal Co., Rochester, N. Y. Sept. 28, 1906

WHITNEY, HENRY M., India Wharf, Boston, Mass. July 12, 1887
Life Member]

WHITNEY, WALTER D., Electrical Engineer, Twin City Rapid Transit Co., 3421 Irving Ave., So. Minneapolis, Minn. Sept. 28, 1906

WHITNEY, WILLIS R., Director Research Laboratory, General Electric Co., Schenectady, N. Y. May 21, 1901

WHITON, CHARLES EDWARD, Assistant Electrical Engineer, Signal Corps, U. S. Army, Washington, D. C. May 15, 1905

WHITTEMORE, GEORGE W., Engineer, Bell Telephone Co., 24 W. Seneca St., Buffalo, N. Y. Jan. 3, 1902

WHITTLESEY, JAMES THOMAS, Chief Engineer, Elec. Dept., Public Service Corporation, Newark, N. J. Nov. 20, 1903

WHITTLESEY, WILLIAM AUGUSTUS, Pittsfield Electric Co., Pittsfield, Mass. Apr. 28, 1905

WIARD, JOHN BULKLEY, Assistant Engineer, General Electric Co.; res., 15 Lakeview Ave., Lynn, Mass. Apr. 23, 1903

WICKERSHAM, EDWARD JAMES, Assistant to Chief Electrician, Chicago, Rock Island & Pacific Ry. Co., Chicago, Ill. Nov. 24, 1905

WICKS, ERNEST BULMER PRIESTLEY, with A. and T. Burt, Dunedin, N. Z. Oct. 26, 1906

WICKS, HAROLD BULMER PRIESTLEY, Scotia, N. Y. Oct. 26, 1906

WICKS, JOHN, Superintendent of Maintenance, Home Telephone and Telegraph Co., San Diego, Cal. Sept. 28, 1906

WIEGAND, HENRY J., Superintendent, Cutler Hammer Mfg. Co.; res., 660 17th St., Milwaukee, Wis. June 21, 1907

WIDDICOMBE, ROBERT A., Engineer and Superintendent, Kroeschell Bros., Co., 55 Erie St., Chicago, Ill. Apr. 26, 1899

WIDEGREN, EMIL HENRIK, Testing Department, General Electric Co., Schenectady, N. Y. Nov. 24, 1905

WIDSTROM, AXEL, Electrical Engineer, Stockholm Electric Works, Tulegatan 13, Stockholm, Sweden. Mar. 24, 1905

WIECHMANN, FERDINAND G., Consulting Chemist, American Sugar Refining Co., 117 Wall St., New York City. Sept. 25, 1903

WIEDERHOLD, OSCAR, Wiederhold Light Co., 131 Winfield Ave., Jersey City, N. J. Aug. 13, 1897

WIEMER, OTTO, Engineer, Wagner Electric Mfg. Co., St. Louis, Mo.; res., 814 Alby St., Alton, Ill. Mar. 29, 1907

WIKANDER, RAGNAR, Allmanna Svenska Elektriska A. B., Westeras, Sweden. Jan. 29, 1904

WILDER, CLIFTON WHITE, Assistant Engineer of Construction, N. Y. C. Interborough Ry. Co., Park Row Bldg., New York City. Mar. 23, 1906

WILDER, GEORGE WALKER, Telephone Engineer, 1761 Monadnock Bldg.; res., 5848 Prairie Ave., Chicago, Ill. Mar. 1, 1907

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WILDER, HENRY WINDSOR, Electrical Engineer, Post and Telegraph Department, Bangkok, Siam. Sept. 27, 1901

WILDER, STUART, Northern Westchester Lighting Co., Ossining, N. Y. May 20, 1902

WILDMAN, LEONARD D., Captain U. S. Signal Corps, Ft., Leavenworth, Kansas. Mar. 27, 1903

WILER, CARL, Electrical Engineer, 581 46th St., Chicago, Ill. Sept. 27, 1901

WILEY, BRENT, Commercial Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Apr. 28, 1905

WILEY, JAMES MELIN, Student, Polytechnic Institute; res,, 793 Sterling Pl., Brooklyn, N. Y. Nov. 23, 1906

WILEY, ROY RODNEY, Electrical Engineer, The Packard Electric Co., Ltd., St. Catharines, Ont. July 28, 1903

WILEY, WM. H., Scientific Expert, 43 E. 19th St., New York City. Feb. 7, 1888

WILHOIT, FREDERIC SHELTON, Assistant Supt., The Cutler-Hammer Mfg. Co.; res., 911 State St., Milwaukee, Wis. May 19, 1903

WILKINS, EDGAR MORRIS, Mexican Lt. & P. Co., Ltd., 3a Industria 52 Mexico D. F., Mex. Dec. 19, 1902

WILKINS, GEORGE BARNUM, Student, Brooklyn Polytechnic Institute, Brooklyn, N. Y. Mar. 29, 1907

WILKINSON, CECIL TOM, General Electric Co.; res., 244 Union St., Schenectady, N. Y. May 14, 1906

WILKINSON, JAMES, Chief Engineer Birmingham Railway, Light and Power Co., Birmingham, Ala. Feb. 28, 1902

WILLARD, FREDERICK ALBERT, Electrical Engineer, Rochester Railway & Light Co., Clinton Ave., Rochester, N. Y. Nov. 24, 1905

WILLCOX, FRANCIS WALLACE, Assistant to Manager, Lamp Sales Dept., Edison Lamp Works, G. E. Co., Harrison, N. J. Mar. 27, 1903

WILLIAMS, ANDREW FULLER, Assistant Operating Superintendent, New York Edison Co., 173 W. 107th St., New York City. Jan. 26, 1906

WILLIAMS, ARTHUR, General Inspector, The New York Edison Co., 57 Duane St., New York City. June 23, 1897

WILLIAMS, CHARLES, JR., Electrician, 1 Arlington St., East Somerville, Mass. Apr. 15, 1884

WILLIAMS, FREDERIC ARTHUR, Chief Engineer, Victory Hotel, Put-in-Bay, Ohio. Nov. 24, 1905

WILLIAMS, GUY VERANUS, Williams & Bernhard Co., Victoria Building, St. Louis, Mo. Mar. 25, 1904

WILLIAMS, HERBERT HOWARD, 442 East Michigan St., Marquette, Mich. Feb. 27, 1903

WILLIAMS, HARRY SMITH, Assistant Electrical Engineer, Utica and Mohawk Valley Railway Co., Utica, N. Y. May 15, 1905

WILLIAMS, JOHN RUTLEDGE, Mechanical Engineer, Birmingham Iron Co., Birmingham, Ala. Dec. 23, 1904

WILLIAMS, LOUIS, Superintendent, United Towns Electrical Co., Ltd., Carbonear, Newfoundland. Mar. 1, 1907

WILLIAMS, PAUL FRANCIS, Assistant General Inspector, Chicago Edison Co., 139 Adams St., Chicago, Ill. Mar. 1, 1907

WILLIAMS, ROBERT NEIL, Power & Mining Department, General Electric Co., Baltimore, Md. Aug. 22, 1902

WILLIAMS, SAMUEL ALFRED, Electrical Contractor, S. A. Williams and Co., Jackson, Miss, Mar. 29, 1907

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WILLIAMS, SAMUEL BORTAR, Cable Engineer, Bell Telephone Co.; res., 608 No. 34th St., Philadelphia, Pa. Apr. 26, 1907

WILLIAMS, SAMUEL BRYON, JR., Telephone Engineer, Western Electric Co., 259 So. Clinton St., Chicago, Ill. Jan. 25, 1907

WILLIAMS, WILLIAM HENRY, Asst. Professor of Electrical Engineering, University of Illinois, Urbana, Ill. Sept. 28, 1898

WILLIAMSON, ALFRED, Assistant Testing Department, General Electric Co.,; res., 110 W. 91st St., New York City. June 15, 1904

WILLIAMSON, ROBERT BAIRD, Engineering Department, Bullock Electric Mfg. Co., Cincinnati, Ohio. Oct. 24, 1902

WILLIS, FREDERICK WILLIAM, Ag. Chief Operator, Cauvery Power Scheme, Champion Reef, Mysore Prov., India. Jan. 29, 1904

WILLIS, JAMES, Student, Columbia University, New York City; res., West New Brighton, S. I., N. Y. May 14, 1906

WILLISTON, H. S., Massachusetts Electric Mfg. Co., 648 Summer St., West Lynn, Mass. Nov. 21, 1902

WILLS, HARRY LEVAQUE, General Manager, Savannah Lighting Co., Savannah, Ga. June 15, 1904

WILLSON, FRANK GARDNER, Instructor in Electrical Engineering, Univ. of Illinois; res., 412 W. Elm St., Urbana, Ill. Nov. 24, 1905

WILSON, ALBERT SWAINE, Inspector Carnegie Steel Works, Hotel Carnegie, Munhall, Pa. Sept. 28, 1906

WILSON, DAVID H., JR., Electrical Engineer, Erie Railroad, Meadville, Pa. Apr. 26, 1907

WILSON, ELIEL FLETCHER, 1108, 8th St., S. E., Minneapolis, Minn. Apr. 27, 1906

WILSON, FRANK REES, Superintendent, Public Service Corporation of N. J., 567 E. 26th St., Paterson, N. J. Mar. 24, 1905

WILSON, HENRY CLINTON, Chief Engineer, American Compound Bearing Co., 25 Broad St., New York City. Sept. 27, 1901

WILSON, HUGH HEATHLEY, Assistant Superintendent, Ontario Power Co., Niagara Falls, Ont. June 19, 1903

WILSON, J. F., Chief Operator, Postal Telegraph Cable Co.; res.,11 Auburndale Ave., Memphis, Tenn. Apr. 26, 1907

WILSON, J. ROBERTS, Salesman, Crocker-Wheeler Co., 912 New England Building, Cleveland, Ohio. May 27, 1903

WILSON, LEONARD, Electrical Engineer, Stanley Electric and Mfg. Co.; res., Beech Grove Inn, Pittsfield, Mass. Sept. 26, 1902

WILSON, NORMAN JAMES, Consulting Electrical Engineer, State Insurance Buildings, Dale St., Liverpool, Eng. Apr. 25, 1902

WILSON, PERCY JAMES, Lowell, Electric Light Corporation, 28 Bridge St., Lowell, Mass. Aug. 25, 1905

WILSON, ROBERT LEE, Superintendent Construction, Westinghouse E. & M. Co., Pittsburg, Pa. June 28, 1901

WILSON, ROBERT M., General Supt. Electrical Dept., Montreal L. H. & P. Co.; res., 23 Seymour Ave., Montreal, P. Q. Jan. 25, 1899

WILSON, SEPTIMUS, Westinghouse Electric and Mfg. Co., Baltimore, Md. Jan. 29, 1904

WILTBERGER, BERTRAM P., with L. B. Stillwell, 1314 Continental Trust Bldg., Baltimore, Md. Mar. 27, 1903

WILY, JAMES HUNTER, Private Assistant. W. S. Franklin, Lehigh University; res., 704 Dakota St., So. Bethlehem, Pa. Mar. 29, 1907

WIMAN, LOUIS ERASTUS, Engineering Department, General Electric Co.; res., 1 State St., Schenectady, N. Y, Dec. 28, 1906

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WINFIELD, JAMES H., General Manager, Nova Scotia Telephone, Ltd., Halifax, N. S. May 17, 1898

WINGO, CHARLES EVANS, JR., Assistant Engineer, Electric Mfg. and Equipment Co.; res., 49 W. Baker St., Atlanta, Ga. Sept. 28, 1906

WINN, HARRY DOUGLAS, Electrical Engineer, Westinghouse Electric and Mfg. Co., 622 Empire Bldg., Atlanta, Ga. June 14, 1905

WINN, JOHN EDWARD, 122 Fourth St., Union Hill, N. J. May 20, 1902

WINSHIP, WALTER EDWIN, Electrical Engineer, Gould Storage Battery Co., 341 Fifth Ave., New York City. May 19, 1903

WINSLOW, CHARLES GARDNER, New York Central and Hudson River R.R., 5 Vanderbilt Ave.; res., Mount Vernon, N. Y. Aug. 22, 1902

WINSLOW, I. E., The General Traction Company, Ltd., 20 Bishopsgate St., (within) London E. C., Eng. Nov. 12, 1889

WINSTON, CHARLES SUMNER, Chief Engineer, Kellogg Switchboard and Supply Co.; res., 5834 Rosalie Ct., Chicago, Ill. Feb. 23, 1906

WINTER, WILLIAM GEORGE, Chief Draftsman, Emerson Electric Mfg. Co., 2648A Oregon Ave., St. Louis, Mo. Mar. 29, 1907

WINTNER, LOUIS, Manager, N. Y. Supply Sales, Stanley G. I. Electric Mfg. Co., 42 Broadway, New York City. May 21, 1901

WINTRINGHAM, J. P., Theorist, Mills Building, 35 Wall St., New York City; res., 135 Henry St., Brooklyn, N. Y. May 7, 1889

WISE, JOHN SHREEVE, JR., Manager, Harwood Electric Power Co., Lattimer Mines, Pa. Feb. 15, 1896

WISWELL, OZRO N., Snoqualmie Falls and White River Power Co., Snoqualmie Falls, Wash. May 17, 1904

WITHERBY, EDWIN E., Engineer and General Manager, United Gas and Electric Co., 40 Wall St., New York City. Mar. 25, 1904

WITHINGTON, BERNARD, Draftsman, Lancashire Dynamos and Motor Co. Ltd., Manchester, Eng. June 21, 1907

WITTIG, GUSTAV [*Local Secretary*], Instructor in Electrical Engineering, University of Maine, Orono, Me. Mar. 24, 1905

WOHLAUER, ALFRED, Electrical Engineer, 26 W. 97th St., New York City. Nov. 20, 1903

WOHLERS, CHARLES, Consulting Engineer, Western Electric Co.; res., 305 E. 40th St., New York City. Sept. 22, 1905

WOLF, HARRY JOHN, Chief Engineer, Superintendent, Stanley Mines, Idaho Springs, Colo. May 14, 1906

WOLF, LEE H., Contracting and Engineering, Honolulu, H. T. Oct. 24, 1900

WOLFE, ERNEST A., Electrical Engineer, 708 Land Title Bldg., Philadelphia, Pa. Nov. 25, 1904

WOLFE, JOSEPH THOMAS, Tonopah Mining Co., Tonopah, Nev. June 28, 1901

WOLFF, FRANK A., Prof. of Physics and Electrical Eng., Col. Univ., and in office Bureau of Standards, Washington, D. C. Dec, 27, 1899

WOLFF, SALOMON, Allis-Chalmers Co., Cleveland, Ohio. Feb. 27, 1903

WOLFF, WILLY AUGUST, Telephone Engineer, Western Electric Co., 463 West St.; res., 320 Manhattan Ave., New York City. Oct. 27, 1905

WOLLS, WILLIAM A., Engineer, 147 Thurman St., Columbus, Ohio. May 17, 1904

WOLTMAN, ERNST, Manager, Albert and J. M. Anderson Mfg. Co., 135 Broadway; res., 610 W. 113th St., New York City. Mar. 29, 1907

WOLTZ, ROSCOE, Roanoke Railway & Electric Co., Roanoke, Va. Dec. 23, 1904

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WOOD, ALBERT E., Trumbull Electric Mfg. Co., Plainville, Conn. Jan. 27, 1905

WOOD, FRANKLIN WASHINGTON, Local Manager, Charles Cory & Son; res., 223 29th St., Newport News, Va. Nov. 24, 1905

WOOD, HARRY PETERMAN, Assistant Professor, Electrical Engineering, University of Illinois; res., Urbana, Ill. Nov. 23, 1906

WOOD, HOWARD JOHN, Chief Draftsman, Office Electrical Engineer B. & O. R.R. Co., Baltimore, Md. Dec. 28, 1906

WOOD, R. HOMER, General Manager, Electric Novelty Appliance Co., 510 E. Main St.; res., 107 N. 4th St., Richmond, Va. Jan. 27, 1907

WOOD, REGINALD JOHN CUMMING, Engineering Department, Edison Electric Co., Los Angeles, Cal. Sept. 28, 1906

WOOD, WALTER, Managing Partner, R. D. Wood and Co., 400 Chestnut St., Philadelphia, Pa. Dec. 23, 1904

WOODARD, D. CARL, Switchboard Operator General Electric Co.; res., 13 Eagle St., Schenectady, N. Y. June 21, 1907

WOODBRIDGE, JOSEPH LESTER, Chief Engineer, Electric Storage Battery Co., 19th St. and Allegheny Ave., Philadelphia, Pa. Apr. 28, 1905

WOODBURY, CHARLES JEPHTA HILL, Secretary, National Association of Cotton Mfrs., Room 501, 45 Milk St., Boston, Mass. Aug. 22, 1902

WOODBURY, DANIEL CORYTON, N. Y. C. & H. R. R.R., Room 1232, Grand Central Station., New York City. Apr. 25, 1902

WOODBURY, EDWARD, Electrician, Pacific Light and Power Co.; res., 2930 Dorchester St., Los Angeles, Cal. Jan. 27, 1905

WOODBURY, STEPHEN EDWARD, Engineer, Simplex Electric Heating Co.; res., 163 Magazine St., Cambridge, Mass. June 21, 1907

WOODFIELD, SYDNEY, Assistant Engineer, Brush Electrical Engineering Co., Ltd., London, S. E., Eng. Feb. 28, 1902

WOODHOUSE, ALBERT LLOYD, General Supt. of Utah Dept., The Telluride Power and Transmission Co., Provo City, Utah. Aug. 22, 1902

WOODMANSEE, FAY, Electrical Engineer, Sargent & Lundy, Railway Exchange, Chicago, Ill. May 17, 1904

WOODWARD, CORNELIUS WENDELL, Purchasing Agt., Electric Storage Bat Co., 19th St. & Allegheny Ave., Philadelphia, Pa. Sept. 26, 1902

WOODWARD, FREDERICK SEARLE, 22 McDonough St., Brooklyn, N. Y. June 28, 1901

WOODWARD, HENRY WILMOT, Secretary, The Cleveland Engineering Co., 1310 New England Building, Cleveland, Ohio. May 19, 1903

WOODWELL, JULIAN ERNEST, Inspector of Electric Lighting Plants, U. S. Treasury Department, Washington, D. C. June 21, 1907

WOODWORTH, GEO. K., Patent Attorney, Browne & Woodworth, 31 State St., Boston, Mass. Feb. 17, 1897

WOODWORTH, LEON BYRON, Electrical Engineer, New Heriot Gold Mining Co., Johannesburg, Transvaal. Nov. 23, 1900

WOODWORTH, PHILIP BELL, Professor of Electrical Engineering, Lewis Institute, Chicago; res., 5808 Ohio St., Austin, Ill. July 12, 1900

WOOLDRIDGE, WILLIAM JOHN, Electrical Engineer, General Electric Co.; res., 1303 Union St., Schenectady N. Y. Sept. 28, 1906

WOOLFENDEN, HENRY L., President and Chief Engineer, Gilbert Wilkes & Co., 435 17th St., Denver, Colo. Mar. 27, 1903

WOOLFENDEN, JOHN JOSEPH, Draftsman, Brush & Allen, 1331 Penobscot Bldg.,; res., 25 E. Alexandrine Ave., Detroit, Mich. June 21, 1907

WOOLFORD, WILLIAM ALLEN, General Electric Co., 1600 Continental Trust Bldg., Baltimore, Md. Oct. 24, 1902

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WOOLISCROFT, JOHN HAROLD, Electrical Engineer, Mount House, Hawarden, Chester, Eng. May 19, 1903

WORCESTER, THOMAS ALFRED, Power and Mining Engineering Dept., General Electric Co., Schenectady, N. Y. Sept. 28, 1906

WORK, WILLIAM ROTH, Instructor in Electrical Practice, Carnegie Technical Schools, Pittsburg, Pa. Jan. 25, 1907

WORSWICK, A. E., with S. Pearson & Son, Ltd., Puente de Alvarado 15, Mexico City. Sept. 20, 1893

WOY, FRANK PALMER, Assistant to Electrical Engineer, J. G. White & Co., 43 Exchange Pl., New York City. July 28, 1903

WRAY, CHARLES CLAREMONT ROBERTS, Electrical Engineer Hazlemere Coleraine Road, Blackheath, London., Eng. Sept. 28, 1906

WRAY, J. GLEN, Engineer, Chicago Telephone Co., 203 Washington St., Chicago; res., 618 Washington Ave., Wilmette, Ill. Sept. 20, 1893

WRIGHT, ARTHUR, Consulting Electrical Engineer, 3 Addison Road, Kensington, London, Eng. Apr. 27, 1906

WRIGHT, CHARLES HARVEY, Engineer, Canadian General Electric Co., Citizen Building, Ottawa, Ont. Dec. 18, 1903

WRIGHT, EDWARD ALBIN, 214 Beckley Building, Rochester, N. Y. Dec. 28, 1906

WRIGHT, EDWIN CAREW, Electrical Engineer, Allis-Chalmers Co., Cincinnati, Ohio. Jan. 25, 1907

WRIGHT, FRANK THOMAS, Draftsman, 67 Mount St., Charlton, S. E. London. Eng. Oct. 23, 1903

WRIGHT, GILBERT, Electrical Engineer, The Stanley Electric Mfg. Co., Pittsfield, Mass. June 19, 1903

WRIGHT, HERBERT W., Electrical Engineer, Stamford Gas & Electric Co., Stamford, Texas. Sept. 28, 1906

WRIGHT, JOHN JOSEPH, General Manager, Toronto Electric Light Co., 12 Adelaide St., E. Toronto, Ont. Aug. 25, 1905

WRIGHT, JOHN WILLIAM, Electrical Engineer, Bell Telephone Co.; res., 5223 Pine St., Philadelphia, Pa. Apr. 27, 1906

WRIGHT, LEON MILLS, Chief Electrician, U. S. Navy, U. S. F. S. "Chicago," San Francisco, Cal. Oct. 26, 1906

WRIGHT, REUBEN IRVING, Assistant Engineer, Electric Controller and Supply Co., Cleveland, O. July 19, 1904

WRIGHT, WALTER FARADAY, Power and Mining Engineering Dept., General Electric Co., Schenectady, N. Y. Sept. 28, 1906

WRIGLEY, GEORGE, Assistant, Engineering Department, General Electric Co., Empire Bldg., Atlanta, Ga. Dec. 19, 1902

WUNDERLICH, ADOLPH, Electrical Engineer, Cuyahoga, Mayfield Road, Sanderstead, Surrey, Eng. July 28, 1903

WURDACK, HUGO, Superintendent of Electric Station, Laclede Gas Light Co.; res., 1221 Euclid Ave., St. Louis, Mo. Dec. 18, 1903

WYLIE, DR. WALKER GILL, President, Southern Power Co.; res., 28 W. 40th St., New York City. Oct. 27, 1905

WYLLIE, ROBERT EDWARD, Captain U. S. Artillery Corps, Manila, P. I. Sept. 25, 1903

WYMAN, WALTER S., Manager, Messalonskee Electric Co., and Oakland Electric Co., Waterville, Me. Jan. 23, 1903

WYNKOOP, HUBERT SCHURMAN, Electrical Engineer, Dept. of Water Supply, Gas & Elec., Municipal Bldg., Brooklyn, N. Y. May 15, 1905

WYNN, JOHN G., Engineer, Northern Electric Mfg. Co.; res., 1223 Jenifer St., Madison, Wis. Dec. 18, 1903

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WYNNE, HENRY JOHN, Signal and Electrical Engineer, Government Railways, Wellington, N. Z. Apr. 27, 1906

YAMAZAKI, SHIRO, Engineer, Fujioka Electric Office, 1 Itchome Yaesumachi Kojimachi-Ku, Tokyo, Japan. Jan. 24, 1902

YARDLEY, JOHN LINN MCKIM, Engineer, Westinghouse Electric & Mfg. Co. Buffalo, N. Y. Mar. 23, 1906

YATES, GEORGE LIVINGSTON, Traffic Chief, New York Telephone Co.; res., 40 South Fifth Ave., Mt. Vernon, N. Y. June 21, 1907

YATES, THOMAS JARVIS, Superintendent City Electric Service, Utah Light and Railway Co., Salt Lake City, Utah. Oct. 26, 1906

YATES, WILLIAM CHAUNCEY, Commercial Engineer, Rheostat Department, General Electric Co., Schenectady, N. Y. Nov. 23, 1906

YAWGER, THOMAS H., Asst. Superintendent, Rochester Gas & Electric Co., 84 Andrews St., Rochester, N. Y. July 19, 1904

YEAKLE, JAMES B., Superintendent of Telegraph, Fire Department, City Hall, Baltimore, Md. June 14, 1905

YEARSLEY, EUGENE WILSON, Electrical Engineer, Midvale Steel Co., Nicetown, Philadelphia, Pa. Mar. 27, 1903

YENSEN, PETER, General Manager, The Cleveland Telephone Co., Telephone Building, Cleveland, Ohio. Mar. 27, 1903

YEREANCE, WILLIAM BURNET, Consulting Engineer, 24 Broad St., New York City; res., 418 Center St., South Orange, N. J. Mar. 24, 1905

YETMAN, CHARLES ELMER, V. P. and General Manager, Yetman Transmitting Typewriter Co., New York City. Jan. 27, 1905

YOCHUM, LOUIS GEORGE, Foreman, Western Electric Co., New York City; res., 466 6th St., Brooklyn, N. Y. June 21, 1907

YORK, BERT STARR, Power Apparatus Salesman, Western Electric Co.; res., 207 Hazel Ave., Chicago, Ill. Apr. 26, 1907

YORKE, GEORGE MARSHALL, Asst. Engineer, American Tele. and Telegraph Co., 15 Dey St.; res., 44 Irving Pl., New York City. Apr. 25, 1902

YOSHISAKA, SUKICHI, Electrical Engineer, 47 2d St., Sannomiya, Kobe, Japan. Aug. 25, 1905

YOUNG, CHARLES I., Electrical Engineer, Westinghouse Elec. & Mfg. Co., 708 Land Title Bldg., Philadelphia, Pa. June 27, 1895

YOUNG, ERNEST JAMES, Electrician, Michigan Lake Superior Power Co., 905 Swinton St., Saulte Ste Marie, Mich. Dec. 15, 1905

YOUNG, FREDERICK WILLIAM, Chief Tester, Crocker-Wheeler Co., Ampere, N.J.; res., 47 William St., East Orange, N. J. Aug. 22, 1902

YOUNG, H. W., Salesman, Westinghouse Electric and Mfg. Co., Pittsburg, Pa., Apr. 28, 1905

YOUNG, JAMES WATTS, The Benedict, 80 Washington Square, New York City. Dec. 18, 1903

YOUNG, WILBUR HUBBELL, Engineering Department, Gould Storage Battery Co., 341 Fifth Ave., New York City. Apr. 26, 1907

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Boston............Feb. 13, '03	Wm. L. Puffer.	C. H. Tapping.	3d Wednesday
Chicago.................1893	H. R. King.	J. G. Wray.	1st Tuesday after N. Y. meeting.
Cincinnati.........Dec. 17, '02	A. G. Wessling.	A. C. Lanier.	
Cleveland.........Sept. 27, '07	Henry B. Dates.	F. M. Hibben.	3d Monday.
Columbus.........Dec. 20, '03	R. J. Feather.	H. L. Backman.	1st Wednesday.
Minnesota..........Apr. 7, '02	H. J. Gille.	Barry Dibble.	2d Monday after N. Y meeting.
Pittsburg..........Oct. 13, '02	C. E. Skinner.	R. A. L. Snyder.	1st Wednesday.
Pittsfield..........Mar. 25, '04	J. Insull.	H. L. Smith.	3d Friday.
Philadelphia.......Feb. 18, '03	J. F. Stevens.	H. F. Sanville.	2d Monday.
San Francisco......Dec. 23, '04	C. L. Cory.	A. H. Babcock.	
Schenectady.......Jan. 26, '03	D. B. Rushmore.	W. C. Andrews.	Every Friday.
Seattle............Jan. 19, '04	C. E. Magnusson.	W. S. Wheeler.	3d Saturday.
St. Louis..........Jan. 14, '03	A. S. Langsdorf.	H. I. Finch.	2d Wednesday.
Toledo............ June 3, '07	W. G. Nagel.	Geo. E. Kirk.	1st Friday.
Toronto..........Sept. 30, '03	K. L. Aitken.	L. W. Pratt.	2d Friday.
Urbana..........Nov. 25, '02	J. M. Bryant.	E. B. Paine.	1st Wednesday after N.Y. meeting.
Washington, D. C...Apr. 9, '03.	P. G. Burton.	Philander Betts.	2d Wednesday.
BRANCHES.			
Armour Institute...Feb 26, '04	T. C. Oehne, Jr.	J. E. Snow.	1st & 3rd Thursdays
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Purdue University..Jan. 26, '03	J. W. Esterline.	H. T. Plumb.	Every Tuesday.
Syracuse University Feb. 24, '05	W. P. Graham	R. A. Porter.	1st and 3d Thursdays.
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Univ. of Colorado..Dec 16, '04	L. R. Handley.	H. S. Buchanan.	1st and 3d Wednesdays
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SINGLE-PHASE VERSUS THREE-PHASE GENERATION FOR SINGLE-PHASE RAILWAYS

BY A. H. ARMSTRONG

The introduction of the alternating-current single-phase railway motor calling for a single-phase secondary distribution system makes it pertinent to inquire into the question of power generation and primary distribution for such systems. While the simplicity of single-phase generation and distribution is unquestioned, it is not always possible or desirable in these days of general power distribution to install a generating station and primary distribution system capable of taking care of alternating-current railway load alone, to the exclusion of synchronous converters and other receiving machinery requiring three-phase input.

As the use of either the single-phase or the multiphase generator seems to be open to certain objections, various methods of distribution are presented herewith, with some of the advantages and disadvantages pertaining to each.

Single-Phase Generation

1. Single-phase generation and transmission makes it impossible to use synchronous converters, self-starting synchronous motors, or induction motors starting under load. Poorly adapted for general power distribution, it is chiefly limited in application to alternating-current railway operation; its use is, therefore, open to grave objections of a commercial nature where there exists any possibility of selling power or in any way utilizing it for general converter and motor work.

2. The single-phase generator has an unbalanced armature reaction which is the cause of considerable flux variation in the

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field pole-tips, and in fact throughout the field structure. In order to minimize eddy currents, such generators must, therefore, be constructed with thinner laminations and oftentimes poorer mechanical construction, resulting in increased cost of the generator. The large single-phase armature reaction results in a much poorer regulation than that obtained with a three-phase generator; it calls for increased amount of field copper; it requires more liberal design; it also requires larger exciting units—these make the cost of the single-phase generating unit throughout considerably more than that of a three-phase unit of the same output and heating.

The difficulties of single-phase generator construction appear to increase with decrease in frequency. The adoption of any lower frequency than 25 cycles may therefore result in serious difficulties in construction for a complete line of machines of the

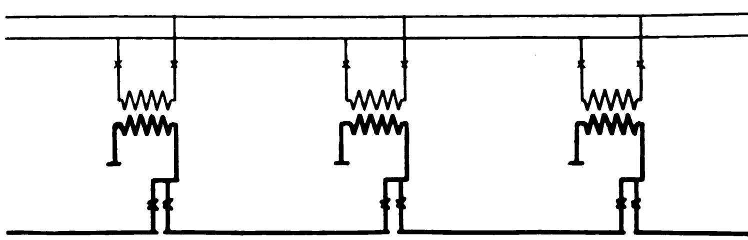

FIG. 1—Single-phase primary and secondary distribution

single-phase type, especially of the two- or four-pole turbine-driven type, where the field flux is very large per pole.

3. To offset the difficulty of single-phase generator construction, its greater cost and poorer efficiency, there are the advantages of simplicity in the entire generating, primary, and secondary distribution systems for single-phase roads. These advantages are so great that they justify considerable expense; looked at from the railway point of view only, the single-phase system throughout may be considered as offering the most advantages.

THREE-PHASE GENERATION

Three-phase generation and distribution is in almost universal use. Many single-phase railways receive power from such systems. The commercial advantages resulting from the use of such generators may in certain cases justify the complication of single-phase secondary distribution obtained from a three-

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phase source. As these commercial advantages are in many cases controlling, various combinations of three-phase--single-phase connections are presented herewith.

1. *Three-phase generation and primary distribution to motor-generator sets feeding into the single-phase secondary distribution.* This system has all the advantages of obtaining power from a three-phase distribution which may also feed synchronous converters and a general power load; it is independent of the frequency of the generating system, being equally adapted for 60 or 25 cycles. It is the only system which will give perfect balance on a three-phase distribution system. Its disadvantage lies in the cost of the motor-generator sub-station.

2. *Three-phase generators operating alternating-current railway load on one leg, thus calling for both primary and secondary single-phase distribution.* Commercial considerations of a pos-

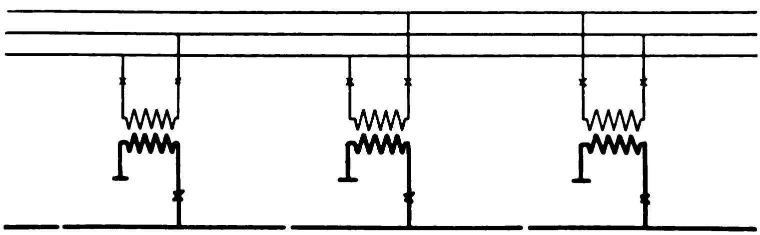

FIG. 2—Three-phase primary and single-phase secondary distribution

sible future synchronous converter or power load may justify the installation of three-phase generators designed for single-phase output for railway load and three-phase output for general power distribution. This system is open to the objection of serious unbalancing due to railway load on one phase only, and this unbalancing may be so great as to cause undue heating in synchronous converters, synchronous motors, and induction motors fed from the unequal potentials of all three legs of the three-phase generator. Tests have been made which indicate that receiving apparatus may have its capacity reduced from 30 to 50 per cent. with normal heating with the unbalancing caused by a single-phase railway load fed from a three-phase generator in commercial operation.

A three-phase generator run as a single-phase generator is open to all the objections of excessive armature reaction, poor regulation, and pulsating flux in field structure noted above for single-

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phase generators. Such generators must be rated single-phase at two-thirds or less of their output when operating on a balanced three-phase load.

3. *Three-phase generation and primary distribution to sub-station, feeding successive trolley sections with separate phases.* Where the length of the road is sufficient to permit sectionalizing the trolley into three sections, or multiples of three, having an equal load on each section, this method provides for balancing the three-phase load, thus securing full output of the generator, non-interference with power load, etc. Each sub-station must contain two sets of transformers connected to separate phases, so that adjacent sub-stations may feed like phases into a common trolley section extending between them. The installation of a single transformer in each sub-station would necessitate the sectionalizing of the trolley midway between sub-stations, hence losing half the effective value of the copper as obtained with the

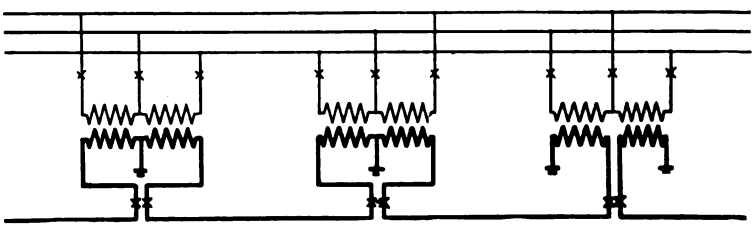

FIG. 3—Three-phase primary and single-phase secondary distribution

trolley sectioned at the sub-stations and two adjacent sub-stations feeding a common trolley section.

This method of obtaining a balanced three-phase load is open to the objection of complication and possible ineffectiveness, with serious disarrangements of schedule such as take place in railway operation during different periods of the day and season.

4. *Two-phase generation, generating station located in center of system and feeding one phase each way.* So long as the load is balanced upon the two primary distribution systems, this method of connection is capable of good results; but operation under the necessities of commercial service shows it to be very difficult to balance the load upon the two phases, thus resulting in considerable unbalancing and extreme voltage variation on the less loaded leg. This same criticism holds true of method 3.

5. *Three-phase generation and primary distribution to transformer sub-stations connected three-phase–two-phase, and*

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feeding secondary distribution in such manner that adjacent sub-stations feed like phases into a common trolley section. This method of connecting is capable of giving good results in operation, although occasional serious unbalancing may occur in the primary distribution with a disarrangement of schedule or improperly proportioned trolley sections. Each sub-station must contain two transformers for regular service, and possibly one spare; these, together with the necessary switchboard arrangement, increases the complexity and cost of such sub-stations compared with the simpler arrangement possible with straight single-phase distribution.

There are other methods of connection, such as independent transmission lines to several outlying sub-stations, thus giving the generating station operator the opportunity to balance the load on the several phases of the generators; but the methods outlined are those commonly proposed for single-phase secondary

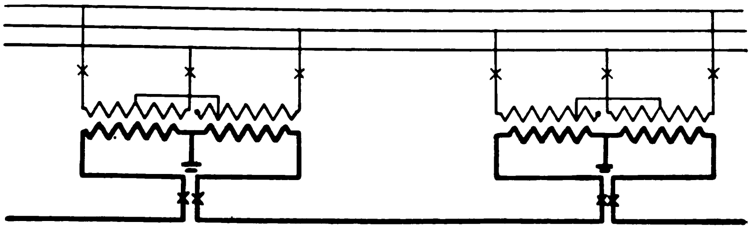

FIG. 4—Three-phase primary and two-phase secondary distribution

distribution used in connection with three-phase generation and primary distribution.

GENERAL CONCLUSIONS

The matter of properly selecting generating apparatus for single-phase roads seems to be closely connected with questions of a commercial nature relating to a possible future load requiring a three-phase input. From a purely engineering standpoint, and considered from the point of view of the railway load only, the single-phase system of generation and distribution is to be recommended. The possible installation of generators having a lower frequency than 25 cycles would help this decision, owing to the unfitness of such a low frequency for general power distribution work.

Of the several methods of single-phase combinations proposed, the motor-generator set best protects the three-phase distribu-

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tion system where power is purchased from foreign distributing systems, and such a method presents many advantages which may outweigh its increased first cost. Where the railway company finds it expedient to generate and distribute its own power from three-phase generators, the use of a single leg for the railway load (3) or the installation of three-phase-two-phase transformer sub-stations (5). Both seem to offer advantages justifying their recommendation, the choice between the two may perhaps be left to the needs of local requirements.

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A paper presented at the 24th Annual Convention of the American Institute of Electrical Engineers, Niagara Falls, N. Y., June 27, 1907.

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THE CHOICE OF FREQUENCY FOR SINGLE-PHASE ALTERNATING-CURRENT RAILWAY MOTORS

BY A. H. ARMSTRONG

Owing to the success attending the several installations of single-phase alternating-current railway motors in this country and abroad, and the suitability of this type of motive power for the electrification of certain steam lines, the questions have been asked as to whether the 25-cycle frequency thus far universally used is the frequency best adapted for alternating-current motor design and operation, or whether the benefits obtained by the use of a lower frequency are sufficient to justify its introduction. This paper is intended to open a discussion on the relative merits of 25 cycles and a lower frequency, and will touch briefly upon the advantages and disadvantages of the present standard of 25 cycles and any proposed standard of a lower frequency.

All the alternating-current railway motor installations thus far made in this country have employed a frequency of 25 cycles, and, with one exception, the service has consisted of the movement of single-car units at maximum speeds of approximately 50 miles an hour at intervals of one-hour headway over a single-track line. That is, all alternating-current roads have been designed to take care of interurban passenger business with the incidental movement of express matter and miscellaneous freight.

It has been found that the alternating-current single-phase commutator motor can be developed to a commercially successful stage at a frequency of 25 cycles; and although some benefits in respect to weight, efficiency, and commutation are to be obtained with the adoption of a lower frequency, the advantages do not as yet seem great enough to justify the standardization of a new frequency suitable to alternating-current com-

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tor motor operation alone. Recognizing the enormous commercial advantage of offering an alternating-current railway motor which could operate from existing power plants, the manufacturers have perfected alternating-current equipments for interurban service for the standard frequency of 25 cycles already universally in use for this class of work.

The introduction of a new frequency calling for the design and establishment of a complete new line of generating, transmitting, and receiving apparatus is a most serious matter; it should not be undertaken without carefully considering all the factors, both commercial and engineering, entering into the case. With the coming electrification of steam roads there is a demand for motors of increased capacity, and the possible limitations of 25-cycle design in large alternating-current motors of certain types is more keenly felt, hence the inquiry at this time into the question of the proper frequency to be adopted when the alternating-current motor is selected as the type of motive power for steam-road electrification.

The various points to be considered may be classed under the following heads:

1. The effect of frequency on design of motor equipment.
2. The effect of frequency on coefficient of adhesion.
3. The effect of frequency on generating and distributing systems.
4. Commercial considerations.
5. Locomotive design and selection of motive power.

The effect of frequency on design of motor equipment. Taking the weight of a direct-current motor as 100 per cent., it is probable that the values in the following table hold approximately true.

COMPARATIVE WEIGHT OF DIRECT-CURRENT AND ALTERNATING-CURRENT MOTORS

Direct Current	25-cycle alternating current	15-cycle alternating current
One-hour capacity 100	150	130
Continuous capacity 100	125	120

These figures apply to motors designed to give in all cases the same output and heating at the same speeds, but with an ad-

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mitted superiority in commutation in motors of direct-current commutating-pole design. While the weight of the 15-cycle alternating-current motor is less than that of the 25-cycle motor, this will be partly offset by an increase of 30 per cent. in the weight of the step-down transformer on the car. Although the car transformer weighs but approximately 20 per cent. of the complete equipment, including control and motors, an increase of 30 per cent. in its weight will practically offset the reduction in motor weight when recourse is had to 15 cycles. Therefore, while there are other advantages in superior commutation, higher efficiency, etc., obtaining with the use of 15 cycles, there is no material reduction in weight of the complete alternating-current motor and control equipment.

Until recently the commutation of alternating-current motors has been considerably poorer than that of direct-current railway motors in use. Various expedients, such as high-resistance leads, lower frequency, etc., have been suggested to improve the commutation and reduce the losses and heating at the brushes. Recent improvements in alternating-current motor design have resulted in the production of an alternating-current single-phase motor which compares very favorably in commutation with any of the standard direct-current railway motors now in operation, although inferior in this respect to the commutating-pole type of direct-current railway motor. In fact the commutation of the alternating-current single-phase motor has been so improved and the commutator losses so reduced with a frequency supply of 25 cycles as to make it unnecessary to adopt any of the above mentioned expedients in order to eliminate commutator troubles.

Where it becomes necessary to design motors for the greatest output per cubic foot of space allowable, as in the case of very large motors designed for locomotives under the restrictions of 4-ft. 8.5-in. gauge and reasonable wheel-base, it is possible that the adoption of a frequency lower than 25 cycles permits a greater latitude in design of alternating-current single-phase motors of certain types.

2. *The effect of frequency on coefficient of adhesion.* The torque delivered to the driving-wheels by the alternating-current commutating motor is of a pulsating character, and its effective value is somewhat less than the uniform torque imparted by the direct-current motor. Experiments show that the effective torque is a function of the frequency of motor

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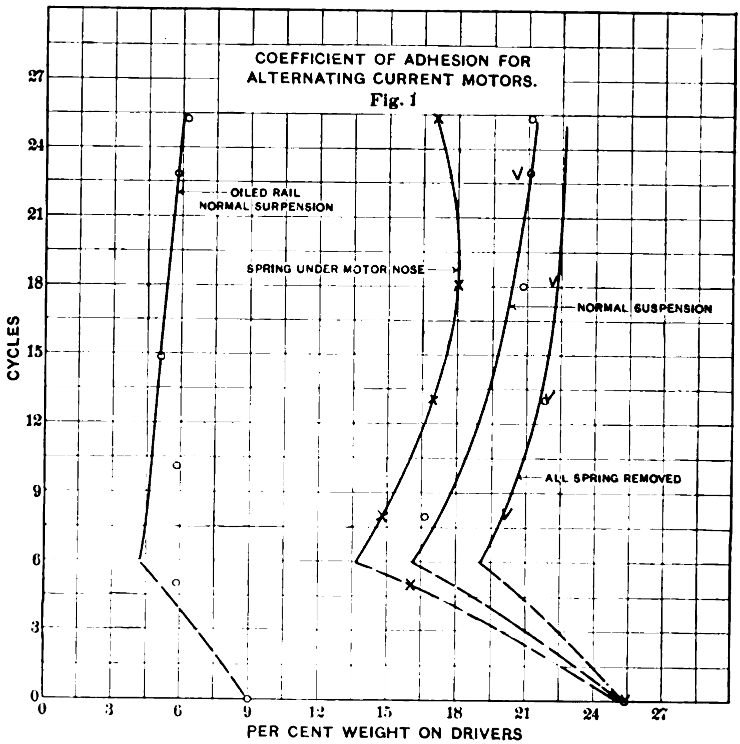
supply, and also depends upon the construction of the truck and the method of motor suspension. The values given in Fig. 1, express the relation between tractive effort and frequency for periods from 25 cycles down to zero; that is, direct current. The values given will hold true only with the combination of truck springs, motor suspension, etc., in the test, and the use of stiffer or lighter springs, more rigid or flexibly suspended motor, the use of springs between gear and axle, etc., might give re-



sults differing considerably in degree from those submitted herewith.

The three curves given represent normal motor suspension, additional spring suspension under the motor nose, and with springs removed, giving practically rigid suspension except for the spring of the armature shaft, gear teeth, etc. While the tests are incomplete, they indicate a slight reduction in the coefficient of adhesion with lower frequency; but so far as can

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be determined this reduction is not a serious matter in the consideration of 25 cycles or a lower frequency, say 15 cycles.

With normal motor suspension, the coefficient of adhesion as obtained with 25 cycles alternating-current was 82.5 per cent. of the value obtained under the same conditions with the same motor supplied with direct current.

3. *The effect of frequency on generating and distributing apparatus.* The question of generator design at 15 cycles is a serious one and presents many difficulties which can only be partly overcome at an increased cost of the apparatus perfected for 25 cycles. In fact, while certain capacities of low-frequency turbo-generator units may be constructed fairly comparable with 25-cycle units, it is probable that the adoption of 15 cycles or less would seriously handicap the standardization of a complete line of such units; in any case it will increase the cost of those units which it is possible to construct. The steam turbine has shown itself a most excellent prime mover, and the adoption of 15 cycles is seriously handicapped by the difficulties opposing the successful construction for this frequency of a complete line of generator units of all sizes.

Both step-up and step-down transformers are handicapped at 15 cycles by an approximate increase in cost of 30 per cent. over that of 25-cycle design. This applies to step-up and step-down transformers used throughout the low-frequency system.

4. *Commercial considerations.* Perhaps the benefits of standardization to both the customer and the manufacturer have not been appreciated to any greater extent than in the electric railroad industry. The universal adoption of 25-cycle three-phase supply feeding into the distributing system of railway networks constituted so strong a claim in favor of adopting this frequency when developing the alternating-current railway motor as to outweigh certain known benefits to be obtained with a lower frequency supply. The great field for alternating-current motors of 150-h.p. capacity and less is on interurban lines acting as feeders to the surface, elevated, and subway lines of large cities. The ability of such motors to run from the same alternating-current generating and distributing systems without requiring the introduction of frequency-changer sets constitutes a strong argument in favor of continuing the present practice of installing 25 cycles on such lines.

The type of apparatus adopted for new installations must necessarily be largely dependent upon the apparatus already

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installed for similar purposes in its neighborhood; it is a question, then, when considering the electrification of steam roads in and about large cities, whether engineers can afford to neglect this principle and cut loose from standards already established and universally used. Furthermore, steam railroad electrification often commences in station and signal lighting and car shops, and 25 cycles is already largely in use for such work. Small motors and transformers are much higher in price at 15 cycles; there is no line developed; and station and car lighting is most unsatisfactory at this frequency.

5. *Locomotive design and selection of motive power.* One of the principle arguments in favor of the electric locomotive is that it permits the concentration of a very large amount of power on the driving-wheels. In this respect the electric locomotive equipped with alternating-current series compensated motors does not compare favorably with other types of motors of both alternating-current and direct-current design. Furthermore, the successful exploitation of these other types of motive power does not demand the adoption of a frequency less than 25 cycles, and hence it is pertinent to inquire if, with our present knowledge of the art, the alternating-current single-phase motor of the series compensated type possesses qualifications which make it so superior to other types of electric motors as to justify the introduction of an odd frequency of benefit only to that one type of motive power. The writer feels much gratified at the success attending the development and operation of the various alternating-current roads already completed, but it should be pointed out that this success has been attained with a frequency of 25 cycles.

Admitting the coming of steam-road electrification, we have not had any demonstration or even convincing figures submitted which would prove beyond doubt the desirability of adopting 15 cycles and the alternating-current series compensated motor to the exclusion of direct-current motors of all types and voltages, three-phase induction motors, or even single-phase alternating-current motors of other types which can be built in large capacities at 25 cycles. In the opinion of the writer it becomes, not the choice of the best frequency for the alternating-current series compensated type of motor, but a question of the proper selection of motive power for the exacting demands of locomotive construction designed for hauling trains of any weight at both high and low

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speeds over roadbeds of any gradient. The question of frequency might well be left in abeyance until the coming of fuller knowledge of the operation of electric locomotives equipped with motors of different types. Considered from the engineering standpoint of alternating-current series compensated motor design alone, the use of 15 cycles offers advantages in the betterment of commutation, efficiency, and output per pound of motor which may justify its adoption, provided that type of motive power it best suited to the needs of the problem in hand. Taking into account, however, the commercial interests involved, and considering the serious claims that may be advanced in favor of other types of electric motors for which a frequency of 25 cycles is well suited, it appears to the writer that much stronger claims for recognition must be brought forth before the adoption of 15 cycles can be seriously considered.

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TWENTY-FIVE VERSUS 15 CYCLES FOR HEAVY RAILWAYS

BY N. W. STORER

At the regular meeting of the Institute, on January 25 of this year, a paper was presented by Messrs. Stillwell and Putnam dealing with the electrification of steam railways and referring briefly to the question of the adoption of a standard frequency for single-phase railways. This question aroused a great deal of interest and was discussed at greater length than any other feature of the paper. The authors, while enumerating the advantages of both 25 and 15 cycles, drew the conclusion that the advantages were greatest on the side of the lower frequency, and this opinion was concurred in by most of those who discussed the matter. Many good points were brought out, but all were more or less general; and while it is obviously impossible for the Institute to standardize at this time a frequency for railways using alternating current, a free and full discussion of the matter can hardly fail to produce good results and to furnish more definite information than was available at the time the paper was presented. The arguments in favor of 25 cycles may be reduced to the following:

1. It is a standard frequency which is in use in a great many plants throughout the country.

2. It is probably better suited for general power distribution and is certainly better for lighting than 15 cycles; therefore any railroad having a 15-cycle plant for operating its road would be somewhat handicapped in power for lighting and shop purposes.

3. The higher frequency is better suited for speeds of steam turbines of small size, it being at present uneconomical to build

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turbo-generators for less than 2000 kw. at 900 rev. per min., which is the maximum available for 15 cycles.

4. Transformers are lighter and cheaper for 25 cycles.

The principal arguments in favor of 15 cycles are:

1. An increase of from 30 to 40 per cent. in the output of a motor of a given size and a consequent reduction in the total number of motors required to operate a railway, and in the cost of equipment.

2. Better performance of the 15-cycle motors, including higher efficiency, higher power-factor and better commutation.

3. Less dead weight to be carried on cars and locomotives.

4. Lower line losses.

The first argument in favor of 25 cycles; namely, that it is a standard frequency in use in a great many plants of the country, is certainly a good one. It is undoubtedly a very serious matter to consider the introduction of a new frequency for any purpose whatsoever. There are, as is well known, a number of frequencies in use at the present time for which there is no justification except that they are in use, and there is no class of service of which we know that cannot be handled with equal efficiency by one of the standard frequencies, with the exception of the alternating-current railway systems. Railway electrification, if developed as every electrical engineer hopes it will be, will mean an undertaking of such magnitude as to make it practically independent of other electrical interests, so that if a frequency differing from the standards now in use will be advantageous it should be adopted.

The second argument in favor of 25 cycles; namely, that it is better suited for power and lighting purposes than 15 cycles, may be granted without admitting that it is a particularly valuable point. Satisfactory lighting can be obtained with 15 cycles by using a low-voltage lamp having a large filament with high thermal capacity. This will be entirely suitable for ordinary railway lighting. While not having as wide a range of speed as is possible with 25 cycles, 15-cycle induction motors can undoubtedly be used to accommodate practically any class of service required of them. The fact that the single-phase commutating motor is more satisfactory on the low frequency may make the low frequency even more satisfactory for shop purposes than the high frequency. In the discussion of the Stillwell-Putnam paper one speaker called attention to the fact that railway companies would probably

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sell a large amount of power along their right-of-way to consumers for various purposes, and stated that 15-cycle current would be unsuitable for such service. In reply to this it is only necessary to call attention to the fact that the voltage on any railway circuit is so variable as to make it absolutely unsuitable for lighting purposes, and it would therefore be necessary to introduce a motor-generator set in order to get good results. This might just as easily be made a frequency-changer to supply current at either 25 or 60 cycles, as might seem best for that particular locality. While this unquestionably destroys some of the simplicity of the scheme, it is undoubtedly what would be necessary in order to give satisfactory service, even if 25 cycles were in use on the railway, unless a separate generator were used for the lighting circuits. It seems therefore that the 15-cycle current would be little or no handicap to the railway company in this respect.

The third argument; namely, that the higher frequency is better suited for speeds of steam turbines is undoubtedly true, but it affects a very small proportion of the work. Heavy railroads will require in practically all cases larger generators than 2000-kw. units. In cases where they do not, high-speed turbines can be used and frequency-changers employed. At the same time we must admit that the last word in regard to steam-turbine design has not yet been spoken, and it may shortly be an easy matter to make comparatively small units for use with 15-cycle generators.

The fourth argument, that transformers are lighter and cheaper for 25 than for 15 cycles is undoubtedly true. There will be a difference of probably 25 per cent. in the cost of the transformers for any given service. This difference must be offset by the difference in the cost of the motors.

The meat of the entire argument for the lower frequency is in the greater output of the motors for a given size and weight. It was well shown in the Stillwell and Putnam paper that the cost of car equipments and locomotives would far overbalance the cost of power houses and transformer stations; and while I do not wish at this time to give a mass of estimates as to the saving, I will adhere to the statement previously made that the output from a motor of a certain size will be increased from 30 to 40 per cent. by the use of 15 instead of 25 cycles. This has been proved by tests on several different motors.

A well known 100-h.p., 25-cycle motor operates with full

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load at a speed of 620 rev. per min., and in the regular one-hour test on the stand has a temperature rise of 89° cent. in commutator and 75° cent. in armature, other parts of the motor being well below 75° cent. Operated at the same speed on 15 cycles, this motor carried a load of 113 h.p. with a maximum temperature rise in commutator of 76.5° cent. and in armature of 72.5° cent. It is safe to say it is good for 115 h.p. with the limiting temperature of 75° cent. in armature. This same motor with a larger number of turns on the field and run on 15 cycles carried at the same speed of 620 rev. per min. a load of 135 h.p. with a temperature rise in commutator of 76° cent., in armature of 75° cent., and in field-coils of 76.5° cent. It is quite safe to rate this motor at 135 h.p. on 15 cycles.

A larger motor carried a load of 255 h.p. with a temperature rise of 71° cent. in commutator and 76° cent. in armature, other temperatures being well below 75° cent. This motor, operated at the same speed under identical conditions on 15 cycles with a load of 300 h.p., rose 73° cent. in commutator and 81° cent. in the armature. With new field-coils having more turns, the motor will carry at least 325 h.p. and probably 340 h.p. with a rise in temperature not exceeding 75° cent.

While these results are all based on the one-hour test, the continuous capacities will have the same increase on 15 cycles. The inference to be drawn from these results is, of course, that the temperature rise being the same for both frequencies, the losses must be approximately the same; and since the output is greater on 15 cycles, the efficiency must therefore be much higher. Further, the tests are all based on 25-cycle motors modified only in field-coils. If the motors are designed especially for the low frequency, the results will be still better.

A comparison of the weights of car equipments for 25 and 15 cycles indicates that there will be an advatnage in favor of the lower frequency, even with the same number of motors. For instance, a four-motor equipment of 100-h.p., 25-cycle motors, with oil-insulated transformer, will weigh approximately 30,000 lb. Such an equipment for 15 cycles would weigh approximately 28,500 lb. The difference is small, but it is in favor of the lower frequency. If two 15-cycle motors of 200 h.p. each, such as are now building, be furnished, the weight of equipment will be reduced to approximately 23,000 lb., or a reduction of 23 per cent. in the weight of the car equipment. While it is perfectly practicable to furnish two motors for a 400-h.p. equipment for

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operation on 15 cycles, it will be necessary to furnish three or four motors for 25 cycles on account of the great increase in the size of the motor. It is therefore absolutely necessary that the 25-cycle equipment weigh considerably more than that for 15 cycles. In the case of smaller motors aggregating 280 h.p. it is possible to furnish a two-motor equipment operating on 25 cycles. There would, however, be a difference in weight of at least 1500-lb. in each motor in favor of the 15-cycle equipment of the same capacity. This would offset the increased weight of the 15-cycle transformers by at least 1000 lb. In every case, therefore, even where the same number of motors are in use for both frequencies, the 15-cycle equipment will be lighter. On account of the smaller motors the motor trucks will also be lighter, the amount of saving here depending upon the size of the motor.

The greatest gain from the use of 15 cycles is to be found in heavy railroading where locomotives are used. In building locomotives it is desirable, on account of the weight, cost, and maintenance charge, to concentrate the power in as few motors as possible consistent with weight on the drivers and the tractive effort desired. We have found that in virtually all cases the weight of useful apparatus on the drivers, even with 15 cycles, is sufficient to give the necessary adhesion without adding dead weight; therefore the use of 15 cycles means that in practically all cases for the locomotive a smaller number of motors can be used than is possible with 25 cycles. It is frequently the case that three motors which are sufficient with a certain size of driver for 15 cycles would have to be replaced by four motors having the same dimensions. It would sometimes happen that three motors necessary for 25 cycles could be replaced by two of the same dimensions for 15 cycles. In the case of locomotives of very high-speed the extra weight entailed by the use of higher frequency motors, and consequently heavier mechanical parts, would increase the weight of the train to such an extent as to call for a considerably larger output from the motors, simply to haul the extra weight. Such a case we have in mind in a high-speed passenger locomotive that has recently been built.

This locomotive is designed to haul a 400-ton train both on heavy grades and at high speeds on a level track. The locomotive as built for 15 cycles weighs approximately 140 tons, and has four motors each with a nominal rating of 500 h.p. With a 400-ton train behind it, this loco-

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motive would thus have to handle a total of 540 tons. A 25-cycle locomotive built to handle a 400-ton train at the same speeds and on the same grades would require six motors of approximately the same dimensions, and these extra motors together with the extra weight of mechanical parts would bring the total weight of the locomotive up to approximately 185 tons. The total weight of train would thus be 585 tons, or an increase of about 8 per cent. The capacity of these motors would be in the neighborhood of 375 h.p., which would be just about sufficient to handle the extra weight. It must be seen at once that the motors for this locomotive would cost 50 per cent. more and the mechanical parts also considerably more. The only parts of the equipment which would cost less would be the transformer and preventive coils, and the control equipment would be enough more expensive to counterbalance this.

In this connection it may be of interest to give a brief description of the locomotive as built. It is of the articulated type, each half of which has two pairs of drivers and a four-wheel truck similar to the standard American type of steam locomotive, the two halves being coupled back to back. The drivers are 72 in. in diameter with 7 ft. 6 in. between centers of axles. On each axle is mounted a gearless motor having a nominal rating of 500 h.p. and a continuous capacity with forced ventilation of about 375 h.p. The motors, weighing approximately 19,500 lb., are spring-supported, mounted, and connected to the drivers in exactly the same way as the motors on the single-phase locomotive for the New York, New Haven & Hartford Railroad. This feature has been described so many times that it is unnecessary to repeat it. The frame of the locomotive is of the standard steam-locomotive type placed outside of the wheels. It is of cast steel connected at the front and rear and at three places between the ends by heavy cast-steel girders. The truck, which is of the standard steam-locomotive pattern, has 36-in. wheels, with a wheel-base of 6 ft. 2 in.

The electrical and other equipment in the cab is mounted on a raised platform which is about 2 ft. above the floor-line and occupies the middle of the cab, allowing for a passageway on either side. There are numerous windows along the sides of the cab which afford excellent light for the inspection of the apparatus. The equipment is extremely simple and accessible. The main transformer, which is designed for 11,000 volts, is

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mounted above the truck, with the top just below the platform in the cab. Directly above the transformer is located the electropneumatic switch-group to which the various taps in the transformer are carried. Back of the switch-group are the preventive coils used in passing from step to step on the transformer, and from these preventive coils runs a single lead to the reverser switch-group, which is placed directly above the main motors. On this raised platform are also placed the motor-driven air-compressor, the motor-driven blower for furnishing air for ventilation of the motors and transformer, and the air reservoirs. Suspended from the structural work between the platform and the Z-bars in the roof of the cab are the oil circuit-breaker in the high-tension circuit leading to the transformer, the small switches used in connection with the auxiliary motors, and the 20-volt battery which is used for operating the valve-magnets in the controller. The high-tension current is collected from the overhead wire by the standard type of pantagraph trolley. On account of the large drivers and the comparatively high position of the apparatus in the cab, the center of gravity of the locomotive is higher than is usual in electric locomotives. The riding qualities of the locomotive are exceptionally good. The weight of the locomotive, as stated, is 140 tons, there being 50,000 lb. on each driving axle and 40,000 lb. on each truck.

In the case of geared locomotives for heavy freight service, there is still the advantage in favor of 15 cycles. Where the same number of motors is used for both frequencies, it will be necessary to use larger wheels for the 25-cycle locomotive. Low-speed locomotives are especially at a disadvantage with 25 cycles. It is possible to make a geared motor with a capacity of 400 to 450 h.p. for slow-speed freight service with 15 cycles, while with 25 cycles a 300-h.p. motor is as powerful as it is practical to use. This means that in the freight service there is virtually the same condition as in passenger service; namely, that about one-third more motors will be required to perform the service. The locomotive will weigh from 10 to 35 per cent. more.

An examination of the efficiency curves for 15-cycle motors compared with those for 25 cycles will show differences in the losses in the motors alone which will mean a considerable difference in the capacity of the power station. This, when added to the power required to haul the extra weight, and the

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increased line-loss due to the higher frequency, will make a difference of from 5 to 15 per cent. in favor of the 15-cycle equipment. Without giving estimates or long tabulated statements, I leave it to the judgment of the members of the Institute to decide whether it is not advisable, with these facts in mind, to recommend a new frequency.

It is well known that when the advent of the first successful single-phase railway motor was announced by Benj. G. Lamme in his historic paper before the Institute in 1902 the frequency which he advocated was 2000 alternations per minute, or $16\frac{2}{3}$ cycles per second. It was believed at that time that this frequency was best suited to meet the many requirements of power plants for railway apparatus. However, owing to the experimental nature of the undertaking, it was deemed advisable to use the standard frequency of 25 cycles until the commercial success of the system was assured. At the same time it was realized that the practical difficulties to be overcome in the single-phase system would be much greater with the higher frequency. Moreover, in the first equipments sold the motors were of comparatively small size, so that the space occupied by them was not limited. Furthermore, the number of motors in an equipment was fixed by conditions other than dimensions and weight, four-motor equipments being selected in nearly every case, partly on account of the prevailing fad for four-motor equipments and partly because most of the equipments were built for operation on both alternating current and direct current. At any rate, aside from the greater difficulties met with in the design of the high-frequency motor in order to get good performance, the question of frequency was of comparatively small importance. Since that time some 15 or 20 roads have been put in commercial operation with single-phase current at 25 cycles. It has been proved beyond doubt that the single-phase motor is a thoroughly practical and commercial machine. At the same time, as was anticipated, all our experience goes to show the advantage to be gained by the use of a lower frequency. This frequency need not be fixed at exactly 15 or $16\frac{2}{3}$ cycles. As far as the motor operation is concerned, a variation of one or two cycles either way will have comparatively little effect; but we believe, for the sake of using proper ratios between this and existing frequencies, that 15 cycles, which is one-fourth of the standard 60-cycle frequency, or $16\frac{2}{3}$ cycles, which is two-thirds of the standard 25-cycle frequency,

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should be adopted for use, especially on heavy railroads. While this will undoubtedly make it necessary for the manufacturing companies to keep a larger variety of apparatus in stock (as there is no doubt that 25-cycle railways will be operated for a long time to come) the advantage to be gained from the lower frequency in the wider use of apparatus will far outweigh any slight disadvantage of this kind.

The mistake made by the blacksmith when he made the template which fixed the gauge of the standard railways at 4 ft. 8.5 in. is a matter of tradition. It is recognized as being one of the most far-reaching mistakes ever made, inasmuch as it has ever since placed a limit on the capacity of the railroads of our country, both by limiting the capacity of steam locomotives and the size of cars, and last but not least, the capacity of electric railway motors and locomotives. What an enormous benefit would be gained from even a paltry increase from 4 ft. 8.5 in. to 5 ft. What powerful machines could be built for a gauge of 6 ft.! But the mistake has been made, and it will cost so much to rectify it, that the boldest of our railway magnates is staggered by the suggestion.

Electrical engineers have an enormous responsibility in deciding upon matters of detail, such as frequency, which will have an effect that will far outlast anyone who has a voice in the matter; and it certainly behooves us as engineers to consider carefully before recommending the continuance of the present standard frequency of 25 cycles, where it imposes such a handicap on the capacity of our transportation systems.

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THE ATTITUDE OF THE TECHNICAL SCHOOL TOWARD THE PROFESSION OF ELECTRICAL ENGINEERING.

BY HENRY H. NORRIS

Introductory. The technical school is primarily an educational institution. The purpose is not to teach trades of any order, nor is it directly to produce business or professional men. The technical school sustains a vital relation to the profession of electrical engineering, and it cannot succeed without an understanding of that relation. On the other hand, the profession cannot use technical graduates efficiently without a knowledge of the purpose underlying their training. That both school and profession are coming to understand their relation is made evident by many signs. Among these may be mentioned the development of graduate-apprentice courses by manufacturing and operating companies, the reduction of manual training and the increase of scientific training in the schools, the formation of employment committees by both companies and schools, and the cordial relations existing between practitioners and teachers. From the first the technical school has stood for the encouragement of useful studies with a scientific foundation. At first undoubtedly too much emphasis was laid upon the practical features of the curriculum, and the attempt was made to do in the laboratory what can only be done in the factory. This and other faults are being corrected by the study of industrial conditions, and the work of the school is being increasingly appreciated by the profession generally.

The purpose of the present paper is to examine the methods of instruction in technical schools in order to ascertain how the requirements are being met, and to note the progress made and

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the prospects for improvement. Instructors in engineering realize that they are engaged in a most important business, that of preparing men for practical usefulness. In any industrial undertaking men are more necessary than money or machines, therefore the technical school works upon the most important element in commercial success. In many ways such a school is like a manufacturing establishment. It secures its raw material from the preparatory schools in the form of boys with crude ideas of practical life, with little conception of the purpose of a technical education, and with a fair preparation in several lines of study. During four years it endeavors by means of separate and assembling processes to produce men who can "do things." Thus the finished product of the technical school forms a most important part of the raw material of manufacture, construction, operation, and commerce.

Resumé of 1903 convention papers on education. At the Niagara Falls Convention of the Institute held in 1903 a profitable session was devoted to the discussion of technical education. Messrs. White, Gherardi, Osborne, and Jackson presented papers dealing with various aspects of the subject. The consensus of opinion expressed in these papers is that the personality of the technical graduate is of more importance than any information which he may have acquired. Professor Jackson emphasized that the function of a technical school is to produce a capacity on the part of the students for becoming engineers. It is the duty of a college to learn how to do this, the inference being that the teaching of special subjects is a means rather than an end. Professor Jackson's synopsis of the ideal engineer states that he is one who is competent to conceive, organize, and direct extended industrial enterprises. Mr. White selected a number of elements of a young man's personality which are important in business, and he summarized the results of a successful education as: (*a*), the satisfaction which results from possession; (*b*), the ability to enjoy good society; (*c*), the practical use which may be made of the training; (*d*), the ability properly to know any subject; and (*e*), the higher rank which will be taken as a result of this training. The employer inquires as to the business judgment, the mental capacity, and other similar characteristics of an applicant for a position. Mr. Gherardi separated the natural ability of a student from his school training. He does not believe that the training of a telephone engineer should be especially different from that of other electrical engi-

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neers, the training of any engineer properly consisting of such studies as will convince him of the necessity of getting facts, teaching him the best method of doing so. Further, these studies should train in the interpretation of engineering data and in reasoning from them. Mr. Osborne dwelt particularly upon the function of shop work in a technical training and pointed out that the training, as then conducted, tended to emphasize the importance of business rather than manufacturing. He argued for a knowledge of accounting, contracts, and other matters of direct importance in engineering.

Magnetic analogy of technical training. The effect of a technical training on a student may be considered as analogous to that of a magnetomotive force upon a piece of steel. The latter possesses the ability to be magnetized on account of the inherent magnetism of its molecules. Before being subjected to the influence of a directive magnetomotive force, these molecules are grouped in such a way that no external effect is produced. When brought into a magnetic field the molecular magnets tend to arrange themselves in the direction of the applied force. The steel then becomes a magnet ready for any one of a number of practical uses. The external magnetomotive force has put nothing into the steel, but has merely supplied the incentive necessary to render available its inherent qualities. In a similar manner the young men entering technical schools possess certain elements and qualities of personality. The young men differ even more than do various samples of steel. The studies and the personality of the teachers supply what is needed to bring out and develop the natural aptitude of the students, and they can do no more. The student gets little that is new from his college course, and if the attempt is made to impart more information to him than is necessary to stimulate him to his best endeavors, his training will be to that extent a failure. Excess training produces saturation in the mind as does excess magnetomotive force in magnetic material. Like most analogies this one cannot be pushed too far. It emphasizes the fact, however, that the efficient training will be the one which aims most carefully at the development of the students' intrinsic qualities.

Problems of technical instruction. The difficulties encountered in technical education are not met in the delivery of certain courses. They result from the attempt so to coördinate these courses as to develop accuracy, quickness of perception, common

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sense, and such qualities. Leading engineers who are employers of technical graduates place greater value upon the personal qualities of the young men than upon their mere ability to produce designs and superintend construction. They expect the schools to turn out men of character as well as attainments. To meet these demands successfully requires attention to the following items: (1), the attraction and retention of desirable students and the exclusion of those not qualified for technical work; (2), the selection of such studies as will stimulate and direct mental activity; (3), the conducting of all courses in such ways as will tend to bring out the desirable personal qualities in the students; and (4), the recommendation to the students of those lines of engineering practice for which they are best suited.

Not a little of the success of all schools depends upon the quality of men who enter and upon the requirement of severe and continuous application. The results of the training depend very largely upon the personality of the student before he enters the institution. They are affected also by influences not directly resulting from study; for example, athletics and social activities. The direct mental effect of the studies is, therefore, not the only result, and possibly not the most important result of the training.

TECHNICAL SCHOOLS.

Historical notes—general. Technical education in this country may be said to have begun with the founding of the United States Military Academy in 1802, although no technical courses, in the modern sense, were given there. After its reorganization in 1817, an excellent system of mathematical and scientific instruction was given, forming a basis for practical army work. The first technical school, Renssalær Polytechnic Institute, began instruction in 1825. A course in civil engineering was gradually established to meet the demand of that time. The object of this school was to teach the application of science to industry, especially to agriculture, domestic economy, the arts, and manufacture. It is evident that the desire of the founder was to elevate the practical arts by a study of the principles underlying them. In 1845 the United States Naval Academy was founded, and another institution was added to the short list of those in which scientific and mathematical instruction was given with a practical end in view. The far-reaching effect of this discipline was noticeable in the early development of electrical engineering by the number of Annapolis and West Point men

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who were attracted to it. This occurred when the technical courses in electrical engineering were in the formative period. The demand of the time was for soundly trained and practical men, and these soon learned enough of electrical applications to enable them to take leading positions. Among these may be mentioned F. J. Sprague, (Annapolis, 1878), Louis Duncan, (Annapolis, 1880), W. D. Weaver, (Annapolis, 1880), S. Dana Greene, (Annapolis, 1883), and O. T. Crosby, (West Point, 1882).

As the demand for scientific and practical instruction increased, schools were established in connection with universities and upon private foundations, but it was not until after the passage of the Morrill Act of 1862 that a great impetus was given to them. The object of this act was particularly to encourage scientific and technical instruction. The results have been far reaching. Previously established schools were strengthened and many new ones were established, each having for its object the training of young people in practical arts. These schools are accomplishing and have accomplished a great work because their instruction has a definite end in view, that of producing independent, useful, and intelligent citizens.

The practical development of the telephone, the generator, the motor, and the electric light between 1870 and 1880 created a demand for technical instruction in electricity. By this time there were at least twenty-five institutions giving practical and scientific work, some like the Worcester Polytechnic Institute giving especial prominence to shop work, others combining the practical and scientific. The best example of the latter class was the Massachusetts Institute of Technology. In 1871 the Stevens Institute of Technology was organized and at once took a leading place through the prominence given by it to experimental engineering. A third class of schools was more purely scientific, being affiliated with the older classical colleges such as Yale, Harvard, Dartmouth, and Union. All of these schools became interested in the applications of electricity and the beginnings of electrical engineering study were made about 1880. The technical instruction in electricity lagged only a few years behind the industrial beginnings.

Historical notes—Sibley College. Among the land-grant colleges one of the most radical and least trammelled by tradition was that of New York State. Founded in spite of the opposition of every college in the state except Columbia, Cornell University was always ready to undertake anything that appeared promising.

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The mechanic arts formed an important part of the curriculum from the start in the fall of 1868. In 1870 the Honorable Hiram Sibley of Rochester, N. Y., provided means for erecting a suitable building for the department and for purchasing the necessary equipment. The first degree of bachelor of mechanical engineering was conferred in 1873. The work in mechanic arts was administered by the late Professor John L. Morris from the beginning until his retirement in 1904. When early in the seventies William A. Anthony, then professor of physics, began experimenting with the "dynamo", the arc-light, and other novelties he received encouragement from President Andrew D. White. Professor Anthony, assisted by Professor G. S. Moler, designed and built in 1875 a Gramme machine and instruments for experimenting with it. Still earlier he had a telegraph line about the campus; this was transformed into a telephone line as soon as the telephone appeared. An arc-light system with underground cable was also operated. All of these electrical applications impelled him to give instruction in physics with special reference to electricity. In the spring of 1883, while visiting the physical laboratory, President White was impressed with the interest in electrical matters manifested by the students. From his association with Ezra Cornell he was familiar with the development of the telegraph and he had also noted the work done with the electric motor in Germany. Among the experiences which he remembered with pleasure were the rides taken in 1879 upon the Siemens train at the Berlin Exposition of that year and upon the Lichterfelde road. He was also pleased with the Jablochkoff candle in Paris. While talking with Professor Anthony about the rapidly developing art, he suggested that there might be occasion for a new course of study, that of electrical engineering. Professor Anthony agreeing with this suggestion, immediately prepared a plan for a course and presented it to the trustees on March 22, 1883. The trustees referred the matter to the faculty and on March 26 authorized the announcement of a course in electrical engineering.* The announcement was made and several students were attracted by it. The register for the following year states:

> The rapid development of the application of electricity has created a demand for thoroughly trained engineers conversant with electrical

* An electrical course had been begun during the previous year at the Massachusetts Institute, but President White had not heard of it, nor had he received any applications for electrical instruction.

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science, especially by companies carrying on telegraphy, electrical lighting, electrical supply and transmission of power, electroplating or the manufacture of electrical machinery and apparatus. Recognizing this demand, at the beginning of the past academic year the trustees of Cornell University began to receive students desiring to fit themselves to enter this new and constantly extending field. While the general studies of the new course are mainly those of the departments of Civil Engineering and Mechanical Engineering, the special studies of the course embrace the theory of electricity, the construction and testing of telegraph lines, cables, and instruments, and of dynamo-machines, and the methods of electrical measurements, electrical lighting, and the electrical transmission of power.

The electrical course proved popular and developed rapidly. Upon the transfer of the late Robert H. Thurston from Stevens Institute to the directorship of Sibley College in 1885, the electrical course was transferred to Sibley College and became a division of the mechanical engineering course, as it is to-day. The change was based upon the necessity for a thorough foundation of mechanics in the study of electrical engineering. As the major part of the work was given in Sibley College it was natural that the students should come under the jurisdiction of that faculty. The test of time has amply demonstrated the wisdom of this arrangement.

Present curriculum at Sibley College. The present curriculum of Sibley College is the result of a continuous attempt to give a practical education upon a scientific foundation. At first much attention was devoted to manual training, but this has given way to the principles of manufacturing. Experimental engineering has had an increasingly large place. The "backbone" of the course in mechanical engineering is mechanics, theoretical and applied. Analytical geometry and the calculus in the first year lead to the mechanics of engineering in the second. The physics and chemistry of the first and second years give a scientific basis for their practical applications. The descriptive geometry of the first year prepares the way for mechanical drawing. In the second year this takes the form of elementary machine design and kinematics, followed by the more advanced machine design in the third year. A limited amount of shop work is given in the first, second, and third years with accompanying lectures on shop administration and kindred topics. Engineering work begins in the third year with the principles and practical applications of steam and electrical machinery. Experimental work in the electrical and mechanical laboratories continues throughout the third and fourth years. During the

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first three years the instruction in mechanical and electrical engineering is identical, Considerable specialization is allowed during the fourth year, the student taking, as a division of general mechanical engineering, electrical, railway, marine or power engineering, machine design, or naval architecture.

Electrical engineering is taught as an application of mechanics, the only difference from other branches of mechanical engineering being in the source of the forces and the methods of transferring and transforming energy. The alternating current is studied from the start upon the ground that it gives a simple, general, and logical application of the laws of mechanics. The students appear to grasp the applications most readily in the following order: transmission lines, transformers, induction motors, alternators, synchronous motors, synchronous converters, continuous-current generators and motors, and special machines and devices. In connection with each of these topics the auxiliaries are discussed in their logical places; for example, with transmission lines; switches, fuses, and lightning protection.

The electrical instruction is three-sided; experimental, analytical, and graphical. In the laboratory numerous experiments are conducted upon various types of machines, and data (facts) are collected. In the class room the performance of the same machines is predicted from the physical laws underlying their operation. In the computing room the theory and the facts are brought together in graphical form and are thus compared and verified. No designing of electrical machinery forms part of the required course, as this is largely empirical, depending upon the judgment and trained instinct of the practical engineer. Instead, the student is taught to predetermine the characteristics of machines from the dimensions and arrangement of their electric and magnetic circuits, each machine being reduced to an equivalent electric circuit. The computing room is a useful adjunct in this work. While it is not possible to have all of the laboratory reports prepared and problems solved under instruction, a beginning is made, the reports being completed at home. The work of the fourth year is not wholly electrical, but a course in power engineering is taken by all. The mechanical laboratory also tends to prevent undue concentration upon the one subject. A course in political economy also draws attention to important phases of business and social activities.

In addition to the required courses, a considerable part of the

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senior year is available for elective work in engineering subjects. The electrical elective studies comprise electric railways, telephone engineering, electrical machinery design, and power generation and distribution. These are given in the second half of the senior year, after the major part of the routine work is complete. Thesis work may be taken as an elective when a suitable subject presents itself for investigation.

The course described is essentially that given in all technical schools, although details and arrangement differ with environment. Sibley College is fortunate in being connected with a

	INDUSTRY	
	PROMPTNESS	
	PERSONALITY	
	ABILITY TO MAKE THINGS GO	
	INTEGRITY	
SCHOLARSHIP	YEARS IN SIBLEY	
	AVERAGE MARK	
	MATHEMATICS	
	PHYSICS AND CHEM.	
	ENGINEERING	

large university which undoubtedly tends to interest the technical students in matters outside their specialties and thus broadens their horizons. On the other hand, the university acknowledges the stimulus received from the technical school through the energy displayed and the practical nature of the studies.

Results of technical education. It requires no further argument to prove that in importance personality precedes scholarship in the makeup of the technical graduate. Some years ago Professor Harris J. Ryan devised the foregoing form to be filled in when an estimate of a student's characteristics was requested.

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This form is still in use by the Employment Committee and it is of great service in making recommendations. The words "excellent," "good," "fair" and "poor" are used in grading the students for the purpose. Proceeding upon the assumption that the personality is of prime importance, the writer, for the purposes of this paper, requested a large number of Sibley alumni of from four to twenty years' standing to state whether or not the training affected honesty, thoroughness, initiative, perseverance, accuracy, conciseness, energy, self-confidence, address, alertness, and loyalty. Practically all testified that these items are affected and as a rule favorably. Further the alumni were asked to arrange these elements in order of importance. The combined result of the recommendations placed them in the following order: 1, honesty; 2, perseverance; 3, accuracy; 4, thoroughness; 5, energy; 6, initiative; 7, address; 8, loyalty; 9, self-confidence; 10, conciseness; and 11, alertness. It is unnecessary to discuss the ways in which these elements are affected by a technical training. Employers are justified in expecting them in the technical graduates and the schools must and do recognize their importance.

Incidentally, the alumni were asked to state which part of their courses, classical, scientific, or technical, was most beneficial. The majority think that the technical studies benefit them most but there is a recognition of the necessity for a scientific basis for the applications. In response to a query as to improvements needed in technical courses, the impression seems to be that the attention of the students should be directed to the purposes to which the principles are to be applied. A few advocate the introduction of cost-accounting, contracts and allied subjects, which are undoubtedly desirable when time permits. A fourth question asked was, "In what particulars have you found your technical training useful?" This elicited many interesting opinions. *Practically none referred to any technical information which had been received in college.* Instead the opinion was that the greatest gain was the habit of scientifically and practically attacking and solving problems as they arise. General adaptability and the faculty of securing information when needed along any line were also mentioned as important.

After all, the best test of a training of any kind is the use made of it. To determine what the Sibley alumni are doing a canvass of the entire number was recently made. From partial returns the following table has been compiled.

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TABLE OF PRESENT OCCUPATIONS OF ALUMNI OF SIBLEY COLLEGE.

(Includes over 80% of the alumni up to 1904)

Occupation.	Number.	Per cent.
1. Mechanical engineer	298	23.20
2. Electrical engineer	170	13.23
3. Designer or draftsman	140	10.90
4. President, vice-president, secretary, treasurer, or member of firm, manufacturing	127	9.88
5. Teacher	114	8.88
6. Sales engineer	107	8.33
7. Consulting engineer	43	3.35
8. Manager or superintendent, operating	41	3.19
9. Non-engineering occupations*	39	3.03
10. Manager or superintendent, manufacturing	32	2.48
11. Foreman	31	2.41
12. Manager or superintendent, constructing	25	1.94
13. Insurance engineer	19	1.48
14. Attorney	18	1.40
15. Army or navy officer	17	1.32
16. Editor or publisher	15	1.17
17. Assayer, geologist, or mining engineer	15	1.17
18. President, vice-president, secretary, treasurer, or partner, constructing	13	1.01
19. Patent examiner	8	0.62
20. President, vice-president, secretary, treasurer, or partner, operating	7	0.54
21. Civil engineer	4	0.31
22. Irrigating engineer	1	0.08
23. City engineer	1	0.08
Total	1285	100.00

Comments. The first three items may require some explanation. By the term " mechanical engineer " is meant those who are rated as such or who are doing general mechanical engineering work. Designers, draftsmen and those engaged in administrative work are classed separately. The same remark applies to electrical engineer. The word " designer " covers those engineers, however prominent, who are primarily engaged in preparing or superintending the preparation of drawings and designs. It is interesting to note the large number engaged in actual engineering work. There is, however, a great tendency on the part of young engineers to enter sales departments.

*The non-engineering occupations are as follows: Bankers 4, car agent 1, chemist 1, dairy farmer 1, dentist 1, druggist 1, flour miller 1, healer 2, hotel manager 1, jeweler 1, librarian 1, mechanics 4, merchants 7, paper hanger 1, photographer 1, physician 1, postal clerk 1, real-estate agents 3, secretary department of public charities 1, stock broker 1, sugar planter 1, time-keeper 1, tobacco dealer 1, tobacco planter 1.

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STANDARDIZATION RULES OF THE A. I. E. E.

New York, June 17, 1907.

Dr. Samuel Sheldon,

President, American Institute Electrical Engineers,
33 West 39th Street,
New York City.

Dear Sir:—

In accordance with a motion made by Dr. Steinmetz, and duly carried at the last Annual Convention of the Institute, at Milwaukee, the Standardization Rules have been revised in form and wording and in accordance with various suggestions received from members of the Institute. This work has been accomplished by the Standards Committee which has held monthly meetings beginning in September last.

Dr. Steinmetz' motion provided that the Standardization Rules when completed by the Committee should be submitted to the Board of Directors for final adoption and promulgation. I therefore submit the revised Standardization Rules through you to the Board of Directors, and request that they be formally approved and adopted.

Respectfully yours,
(Signed) Francis B. Crocker,
Chairman, Standards Committee.

STANDARDS COMMITTEE.

FRANCIS B. CROCKER, Chairman, Columbia University, New York, N. Y.

ARTHUR W. BERRESFORD, Milwaukee.
DUGALD C. JACKSON, Madison, Wis.
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HENRY G. STOTT, New York, N. Y.
CHARLES P. STEINMETZ, Schenectady.
SAMUEL W. STRATTON, Washington, D.C.
ELIHU THOMSON, Lynn, Mass.

Approved by vote of the Board of Directors, June 21, 1907.

RALPH W. POPE,
Secretary.

New York, June 21, 1907.

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STANDARDIZATION RULES

of the

American Institute of Electrical Engineers.

GENERAL PLAN

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- D. Regulation
  - (I) Definitions
  - (II) Conditions for and Tests of Regulation.
- E. Insulation
  - (I) Insulation Resistance
  - (II) Dielectric Strength
    - (*A*) Test Voltages
    - (*B*) Methods of Testing
    - (*C*) Methods for Measuring the Test Voltage.
    - (*D*) Apparatus for supplying Test Voltage.
- F. Conductivity
- G. Rise of Temperature
  - (I) Measurement of Temperature
    - (*A*) Methods
    - (*B*) Normal Conditions for Tests
  - (II) Limiting Temperature Rise
    - (*A*) Machines in General
    - (*B*) Rotary Induction Apparatus
    - (*C*) Static Induction Apparatus
    - (*D*) Rheostats
    - (*E*) Limits Recommended in Special Cases
- H. Overload Capacities

III. VOLTAGES AND FREQUENCIES

- A. Voltages
- B. Frequencies

IV. GENERAL RECOMMENDATIONS

V. APPENDICES AND TABULAR DATA

- Appendix A.—Notation
- Appendix B.—Railway Motors
  - (I) Rating
  - (II) Selection of Motor for Specified Service
- Appendix C.– Photometry and Lamps
- Appendix D.—Sparking Distances
- Appendix E.—Temperature Coefficients

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I. DEFINITIONS AND TECHNICAL DATA.

1 *Note*: The following definitions and classifications are intended to be practically descriptive and not scientifically rigid.

A. DEFINITIONS. CURRENTS.

2 A Direct Current is a unidirectional current.
3 A Continuous Current is a steady, or non-pulsating, direct current.
4 A Pulsating Current is a current equivalent to the superposition of an alternating current upon a continuous current.
5 An Alternating Current is a current which, when plotted, consists of half-waves of equal area in successively opposite directions from the zero line.
6 An Oscillating Current is a current alternating in direction, and of decreasing amplitude.

B. DEFINITIONS. ROTATING MACHINES.

7 A Generator transforms mechanical power into electrical power.
8 A Direct-Current Generator produces a direct current that may or may not be continuous.
9 An Alternator or Alternating-Current Generator produces alternating current, either single-phase or polyphase.
10 A Polyphase Generator produces currents differing symmetrically in phase: such as two-phase currents, in which the terminal voltages on the two circuits differ in phase by 90 degrees; or three-phase currents, in which the terminal voltages on the three circuits differ in phase by 120 degrees.
11 A Double-Current Generator produces both direct and alternating currents.
12 A Motor transforms electrical into mechanical power.
13 A Booster is a machine inserted in series in a circuit to change its voltage. It may be driven by an electric motor (in which case it is termed a motor-booster) or otherwise.
14 A Motor-Generator is a transforming device consisting of a motor mechanically connected to one or more generators.
15 A Dynamotor is a transforming device combining both motor and generator action in one magnetic field, with two armatures; or with an armature having two separate windings and independent commutators.
16 A Converter is a machine employing mechanical rotation in changing electrical energy from one form into another. A converter may belong to either of several types, as follows:
17 *a*. A Direct-Current Converter converts from a direct current to a direct current.
18 *b*. A Synchronous Converter (commonly called a rotary converter) converts from an alternating to a direct current, or *vice versa*.
19 *c*. A Motor-Converter is a combination of an induction motor with a synchronous converter, the secondary of the former feeding the armature of the latter with current at some frequency other than the impressed frequency; *i.e.*, it is a synchronous converter concatenated with an induction motor.
20 *d*. A Frequency-Converter converts from an alternating-current system of one frequency to an alternating-current system of another frequency, with or without a change in the number of phases or in voltages.
21 *e*. A Rotary Phase Converter converts from an alternating-current system of one or more phases to an alternating-current system of a different number of phases, but of the same frequency.

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C. DEFINITIONS. STATIONARY INDUCTION APPARATUS.

22 STATIONARY INDUCTION APPARATUS change electric energy to electric energy through the medium of magnetic energy. They comprise several forms, distinguished as follows:

23 *a.* In TRANSFORMERS the primary and secondary windings are insulated from one another.

24 *b.* In AUTO-TRANSFORMERS, also called compensators, a part of the primary winding is used as a secondary winding, or conversely.

25 *c.* In POTENTIAL REGULATORS a coil is in shunt and a coil is in series with the circuit, so arranged that the ratio of transformation between them is variable at will. They are of the following three classes:

26 (*a*) COMPENSATOR POTENTIAL REGULATORS in which a number of turns of one of the coils are adjustable.

27 (*b*) INDUCTION POTENTIAL REGULATORS in which the relative positions of the primary and secondary coils are adjustable.

28 (*c*) MAGNETO POTENTIAL REGULATORS in which the direction of the magnetic flux with respect to the coils is adjustable.

29 *d.* REACTORS, or REACTANCE COILS, formerly called choking coils, are a form of stationary induction apparatus used to produce reactance or phase displacement.

D. GENERAL CLASSIFICATION OF APPARATUS.

30 COMMUTATING MACHINES. Under this head may be classed the following: Direct-current generators; direct-current motors; direct-current boosters; motor-generators; dynamotors; converters, compensators or balancers; closed-coil arc machines, and alternating-current commutating motors.

31 Commutating machines may be further classified as follows:

32 *a.* DIRECT-CURRENT COMMUTATING MACHINES, which comprise a magnetic field of constant polarity, a closed-coil armature, and a multisegmental commutator connected therewith.

33 *b.* ALTERNATING-CURRENT COMMUTATING MACHINES, which comprise a magnetic field of alternating polarity, a closed-coil armature, and a multisegmental commutator connected therewith.

34 *c.* SYNCHRONOUS COMMUTATING MACHINES, which comprise synchronous converters, motor converters and double-current generators.

35 SYNCHRONOUS MACHINES, which comprise a constant magnetic field, and an armature receiving or delivering alternating-currents in synchronism with the motion of the machine; *i.e.*, having a frequency equal to the product of the number of pairs of poles and the speed of the machine in revolutions per second.

36 STATIONARY INDUCTION APPARATUS, which include transformers, autotransformers, potential regulators, and reactors or reactance coils.

37 ROTARY INDUCTION APPARATUS, or INDUCTION MACHINES, which include apparatus wherein the primary and secondary windings rotate with respect to each other; *i.e.*, induction motors, induction generators, frequency converters, and rotary phase converters.

38 UNIPOLAR or ACYCLIC MACHINES, in which the voltage generated in the active conductors maintains the same direction with respect to those conductors.

39 RECTIFYING APPARATUS, PULSATING-CURRENT GENERATORS.

40 ELECTROSTATIC APPARATUS, such as condensers, etc.

41 ELECTROCHEMICAL APPARATUS, such as batteries, etc.

42 ELECTROTHERMAL APPARATUS, such as rheostats, heaters, etc.

43 PROTECTIVE APPARATUS, such as fuses, lightning arresters, etc.

44 LUMINOUS SOURCES.

E. MOTORS. SPEED CLASSIFICATION.

45 MOTORS may, for convenience, be classified with reference to their speed characteristics as follows:

46 *a.* CONSTANT-SPEED MOTORS, in which the speed is either constant or does not materially vary; such as synchronous motors, induction motors with small slip, and ordinary direct-current shunt motors.

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47 *b*. MULTISPEED MOTORS (two-speed, three-speed, etc.), which can be operated at any one of several distinct speeds, these speeds being practically independent of the load, such as motors with two armature windings.

48 *c*. ADJUSTABLE-SPEED MOTORS, in which the speed can be varied gradually over a considerable range; but when once adjusted remains practically unaffected by the load, such as shunt motors designed for a considerable range of field variation.

49 *d*. VARYING-SPEED MOTORS, or motors in which the speed varies with the load, decreasing when the load increases; such as series motors.

F. DEFINITION AND EXPLANATION OF TERMS.

(I) *LOAD FACTOR.*

50 The LOAD FACTOR of a machine, plant or system is the ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain interval of time, such as a day or a year, and the maximum is taken over a short interval of the maximum load within that interval.

51 In each case the interval of maximum load should be definitely specified. The proper interval is usually dependent upon local conditions and upon the purpose for which load factor is to be determined.

(II) *NON-INDUCTIVE LOAD AND INDUCTIVE LOAD.*

52 A non-inductive load is a load in which the current is in phase with the voltage across the load.

53 An inductive load is a load in which the current lags behind the voltage across the load. A load in which the current leads the voltage across the load is sometimes called an anti-inductive load.

(III) *POWER-FACTOR AND REACTIVE FACTOR.*

54 The POWER-FACTOR in alternating-current circuits or apparatus is the ratio of the electric power in watts to the apparent power in volt-amperes. It may be expressed as follows:

$$\frac{\text{true power}}{\text{apparent power}} = \frac{\text{watts}}{\text{volt-amperes}} = \frac{\text{energy current}}{\text{total current}} = \frac{\text{energy voltage}}{\text{total voltage}}$$

55 The REACTIVE FACTOR is the ratio of the wattless volt-amperes (*i.e.*, the product of the wattless component of current by voltage, or wattless component of voltage by current) to the total amperes. It may be expressed as follows:

$$\frac{\text{wattless volt-amperes}}{\text{total volt-amperes}} = \frac{\text{wattless current}}{\text{total current}} = \frac{\text{wattless voltage}}{\text{total voltage}}$$

56 POWER-FACTOR and REACTIVE FACTOR are related as follows: If p = power-factor, q = reactive-factor, then with sine waves of voltage and current,

$$p^2 + q^2 = 1$$

With distorted waves of voltage and current,

$$p^2 + q^2 = \text{or} < 1$$

(IV) *SATURATION-FACTOR.*

57 The SATURATION-FACTOR of a machine is the ratio of a small percentage increase in field excitation to the corresponding percentage increase in voltage thereby produced. The saturation factor is, therefore, a criterion of the degree of saturation attained in the magnetic circuits at any excitation selected. Unless otherwise specified, however, the saturation factor of a machine refers to the excitation existing at normal rated speed and voltage. It is determined from measurements of saturation made on open circuit at rated speed.

58 The PERCENTAGE OF SATURATION of a machine at any excitation may be found from its saturation curve of generated voltage as ordinates, against

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excitation as abscissas, by drawing a tangent to the curve at the ordinate corresponding to the assigned excitation, and extending the tangent to intercept the axis of ordinates drawn through the origin. The ratio of the intercept on this axis to the ordinate at the assigned excitation, when expressed in percentage, is the percentage of saturation and is independent of the scale selected for excitation and voltage. This ratio is equal to the reciprocal of the saturation-factor at the same excitation, deducted from unity. Thus, if f be the saturation factor and p the percentage of saturation ratio,

$$p = 1 - \frac{1}{f}$$

(V) *VARIATION AND PULSATION.*

59 The Variation in Prime Movers which do not give an absolutely uniform rate of rotation or speed, as in reciprocating steam engines, is the maximum angular displacement in position of the revolving member expressed in degrees, from the position it would occupy with uniform rotation, and with one revolution taken as 360°.

60 The Pulsation in Prime Movers is the ratio of the difference between the maximum and minimum velocities in an engine-cycle to the average velocity.

61 The Variation in Alternators or alternating-current circuits in general is the maximum difference in phase of the generated voltage wave from a wave of absolutely constant frequency, expressed in electrical degrees (one cycle equals 360 degrees) and may be due to the variation of the prime mover.

62 The Pulsation in Alternators or alternating-current circuits, in general, is the ratio of the difference between maximum and minimum frequency during an engine cycle to the average frequency.

63 Relation of Variation in prime mover and alternator.

64 If n = number of pairs of poles, the variation of an alternator is n times the variation of its prime mover, if direct-connected, and n/p times the variation of the prime mover if rigidly connected thereto in the velocity ratio p.

II. PERFORMANCE SPECIFICATIONS AND TESTS.

A. RATING.

65 Rating by Output. All electrical apparatus should be rated by output and not by input. Generators, transformers, etc., should be rated by electrical output: motors by mechanical output.

66 Rating in Kilowatts. Electrical power should be expressed in kilowatts, except when otherwise specified.

67 Apparent Power, Kilovolt-Amperes. Apparent power in alternating-current circuits should be expressed in kilovolt-amperes as distinguished from real power in kilowatts. When the power factor is 100 per cent., the apparent power in kilovolt-amperes is equal to the kilowatts.

68 The Rated (Full-Load) Current is that current which, with the rated terminal voltage, gives the rated kilowatts, or the rated kilovolt-amperes. In machines in which the rated voltage differs from the no-load voltage, the rated current should refer to the former.

69 Determination of Rated Current. The rated current may be determined as follows: If P = rating in watts, or apparent watts if the power factor be other than 100 per cent., and E = full-load terminal voltage, the rated current per terminal is:

70 $I = \frac{P}{E}$ in a direct-current machine or single-phase alternator.

71 $I = \frac{1}{\sqrt{3}} \frac{P}{E}$ in a three-phase alternator.

72 $I = \frac{1}{2} \frac{P}{E}$ in a two-phase alternator.

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73 NORMAL CONDITIONS. The rating of machines or apparatus should be based upon certain normal conditions to be assumed as standard, or to be specified. These conditions include voltage, current, power-factor, frequency, wave shape and speed; or such of them as may apply in each particular case. Performance tests should be made under these standard conditions unless otherwise specified.

74 *a.* POWER FACTOR. Alternating-current apparatus should be rated in kilowatts, at 100 per cent. power factor; *i.e.*, with current in phase with terminal voltage, unless a phase displacement is inherent in the apparatus or is specified. If a power factor other than 100 per cent. is specified, the rating should be expressed in kilovolt-amperes and power factor, at rated load.

75 *b.* WAVE SHAPE. In determining the rating of alternating-current machines or apparatus, a sine wave shape of alternating current and voltage is assumed, except where a distorted wave shape is inherent to the apparatus. See Secs. 79–83.

76 FUSES. The rating of a fuse should be the maximum current which it will continuously carry.

77 CIRCUIT-BREAKERS. The rating of a circuit-breaker should be the maximum current which it is designed to carry continuously.

78 *a.* NOTE. In addition thereto, the maximum current and voltage at which a fuse or a circuit-breaker will open the circuit should be specified. It is to be noted that the behavior of fuses and of circuit-breakers is much influenced by the amount of electric power available on the circuit.

B. WAVE SHAPE.

79 The SINE WAVE should be considered as standard, except where a difference in the wave form from the sinusoidal is inherent in the operation of the apparatus.

80 A MAXIMUM DEVIATION of the wave from sinusoidal shape not exceeding 10 per cent. is permissible, except when otherwise specified.

81 The DEVIATION of wave form from the sinusoidal is measured by determining the form by oscillograph or wave meter, computing therefrom the equivalent sine wave of equal length, superposing the latter upon the observed wave in such a manner as to give least difference, and then dividing the maximum difference at any ordinate by the maximum value of the equivalent sine wave.

82 The EQUIVALENT SINE WAVE is a sine wave having the same frequency and the same effective or r.m.s. (root of mean square) value as the actual wave.

83 NON-SINE WAVES. The phase displacement between two waves which are not sine waves, is that phase displacement between their equivalent sine waves which would give the same average product of instantaneous values as the actual waves; *i.e.*, the same electro-dynamometer reading.

C. EFFICIENCY.

(I) *DEFINITIONS.*

84 The EFFICIENCY of an apparatus is the ratio of its net power output to its gross power input.

85 *a.* NOTE. An exception should be noted in the case of storage batteries or apparatus for storing energy in which the efficiency, unless otherwise qualified, should be understood as the ratio of the energy output to the energy intake in a normal cycle. An exception should also be noted in the case of luminous sources.

86 APPARENT EFFICIENCY. In apparatus in which a phase displacement is inherent to their operation, apparent efficiency should be understood as the ratio of net power output to volt-ampere input.

87 *a.* NOTE. Such apparatus comprise induction motors, reactive synchronous converters, synchronous converters controlling the voltage of an alternating-current system, self-exciting synchronous motors, potential regulators and open magnetic circuit transformers, etc.

88 *b.* NOTE. Since the apparent efficiency of apparatus delivering electric power depends upon the power-factor of the load, the apparent efficiency, unless otherwise specified, should be referred to a load power-factor of unity.

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(II) DETERMINATION OF EFFICIENCY.

89 METHODS. Efficiency may be determined by either of two methods, viz.: by measurement of input and output; or, by measurement of losses.

90 *a.* METHOD OF INPUT AND OUTPUT. The input and output may both be measured directly. The ratio of the latter to the former is the efficiency.

91 *b.* METHOD BY LOSSES. The losses may be measured either collectively or individually. The total losses may be added to the output to derive the input, or subtracted from the input to derive the output.

92 COMPARISON OF METHODS. The output and input method is preferable with small machines. When, however, as in the case of large machines, it is impracticable to measure the output and input; or when the percentage of power loss is small and the efficiency is nearly unity, the method of determining efficiency by measuring the losses should be followed.

93 ELECTRIC POWER should be measured at the terminals of the apparatus. In tests of polyphase machines, the measurement of power should not be confined to a single circuit but should be extended to all the circuits in order to avoid errors of unbalanced loading.

94 MECHANICAL POWER in machines should be measured at the pulley, gearing, coupling, etc., thus excluding the loss of power in said pulley, gearing or coupling, but including the bearing friction and windage. The magnitude of bearing friction and windage may be considered, with constant speed, as independent of the load. The loss of power in the belt and the increase of bearing friction due to belt tension should be excluded. Where, however, a machine is mounted upon the shaft of a prime mover, in such a manner that it cannot be separated therefrom, the frictional losses in bearings and in windage, which ought, by definition, to be included in determining the efficiency, should be excluded, owing to the practical impossibility of determining them satisfactorily.

95 In AUXILIARY APPARATUS, such as an exciter, the power lost in the auxiliary apparatus should not be charged to the principal machine, but to the plant consisting of principal machine and auxiliary apparatus taken together. The plant efficiency in such cases should be distinguished from the machine efficiency.

96 NORMAL CONDITIONS. Efficiency tests should be made under normal conditions herein set forth and which are to be assumed as standard. These conditions include voltage, current, power-factor, frequency, wave shape, speed and barometric pressure, temperature, or such of them as may apply in each particular case. Performance tests should be made under these standard conditions unless otherwise specified. See Secs. 73-75.

97 *a.* TEMPERATURE. The efficiency of all apparatus, except such as may be intended for intermittent service, should be either measured at, or reduced to, the temperature which the apparatus assumes under continuous operation at rated load, referred to a room temperature of 25° C. See Secs. 267-292.

98 With apparatus intended for intermittent service, the efficiency should be determined at the temperature assumed under specified conditions.

99 *b.* POWER FACTOR. In determining the efficiency of alternating-current apparatus, the electric power should be measured when the current is in phase with the voltage, unless otherwise specified, except when a definite phase difference is inherent in the apparatus, as in induction motors, induction generators, frequency converters, etc.

100 *c.* WAVE SHAPE. In electrical apparatus, the sine wave should be considered as standard, except where a difference in the wave form from the sinusoidal is inherent in the operation of the apparatus. See Secs. 79-83.

(III) MEASUREMENT OF LOSSES.

101 LOSSES. The usual sources of losses in electrical apparatus and the methods of determining these losses are as follows:

102 (*A*) BEARING FRICTION AND WINDAGE.

The magnitude of bearing friction and windage (which may be considered as independent of the load) is conveniently measured by driving

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the machine from an independent motor, the output of which may be suitably determined. See Sec. 94.

(*B*) Commutator Brush Friction.

103 The magnitude of the commutator brush friction (which may be considered as independent of the load) is determined by measuring the difference in power required for driving the machine with brushes on and with brushes off (the field being unexcited).

(*C*) Collector-Ring Brush Friction.

104 Collector-ring brush friction may be determined in the same manner as commutator brush friction. It is usually negligible.

(*D*) Molecular Magnetic Friction and Eddy Currents.

105 These losses include those due to molecular magnetic friction and eddy currents in iron and copper and other metallic parts, also the losses due to currents in the cross-connections of cross-connected armatures.

106 In Machines these losses should be determined on open circuit and at a voltage equal to the rated voltage $+I\,r$ in a generator, and $-I\,r$ in a motor, where I denotes the current strength and r denotes the internal resistance of the machine. They should be measured at the correct speed and voltage, since they do not usually vary in any definite proportion to the speed or to the voltage.

107 Note. The Total Losses in bearing friction and windage, brush friction, magnetic friction and eddy currents can, in general, be determined by a single measurement by driving the machine with the field excited, either as a motor, or by means of an independent motor.

108 Retardation Method. The no-load iron, friction, and windage losses may be segregated by the Retardation Method, in which the generator should be brought up to full speed (or, if possible, to about 10 per cent. above full speed) as a motor, and, after cutting off the driving power and excitation, frequent readings should be taken of speed and time, as the machine slows down, from which a speed-time curve can be plotted. A second curve should be taken in the same manner, but with full field excitation; from the second curve the iron losses may be found by subtracting the losses found in the first curve.

109 The speed-time curves can be plotted automatically by belting a small separately excited generator (say 1/10 kw.) to the generator shaft and connecting it to a recording voltmeter. When the retardation method is not feasible, the frictional losses in bearings and in windage, which ought, by definition, to be included in determining the efficiency, may be excluded; but this should be expressly stated.

(*E*) Armature-Resistance Loss.

110 This loss may be expressed by $p\,I^2\,r$; where r = resistance of one armature circuit or branch, I = the current in such armature circuit or branch, and p = the number of armature circuits or branches.

(*F*) Commutator Brush and Brush-Contact Resistance Loss.

111 It is desirable to point out that with carbon brushes these losses may be considerable in low-voltage machines.

(*G*) Collector-Ring and Brush-Contact Resistance Loss.

112 This loss is usually negligible, except in machines of extremely low voltage or in unipolar machines.

(*H*) Field Excitation Loss.

113 With separately excited fields, the loss of power in the resistance of the field coils alone should be considered. With either shunt- or series-field windings, however, the loss of power in the accompanying rheostat should also be included, the said rheostat being considered as an essential part of the machine, and not as separate auxiliary apparatus.

114 (*I*) Load Losses.

The load losses may be considered as the difference between the total losses under load and the sum of the losses above specified.

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115 *a.* In COMMUTATING MACHINES of small field distortion, the load losses are usually trivial and may, therefore, be neglected. When, however, the field distortion is large, as is shown, for instance, by the necessity for shifting the brushes between no load and full load, or with variations of load, these load losses may be considerable, and should be taken into account. In this case the efficiency may be determined either by input and output measurements, or the load losses may be estimated by the method of Sec. 116.

116 *b.* ESTIMATION OF LOAD LOSSES. While the load losses cannot well be determined individually, they may be considerable and, therefore, their joint influence should be determined by observation. This can be done by operating the machine on short-circuit and at full-load current, that is, by determining what may be called the "short-circuit core loss." With the low field intensity and great lag of current existing in this case, the load losses are usually greatly exaggerated.

117 One-third of the short-circuit core loss may, as an approximation, and in the absence of more accurate information, be assumed as the load loss.

(IV) *EFFICIENCY OF DIFFERENT TYPES OF APPARATUS.*

(*A*) DIRECT-CURRENT COMMUTATING MACHINES.

118 In DIRECT-CURRENT COMMUTATING MACHINES the losses are:

119 *a.* BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

120 *b.* MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of Losses (*D*), Sec. 105.

121 *c.* ARMATURE RESISTANCE LOSSES. See Measurement of Losses (*E*), Sec. 110.

122 *d.* COMMUTATOR BRUSH FRICTION. See Measurement of Losses (*B*), Sec. 103.

123 *e.* COMMUTATOR BRUSH AND BRUSH CONTACT RESISTANCE. See Measurement of Losses (*F*), Sec. 111.

124 *f.* FIELD EXCITATION LOSS. See Measurement of Losses (*H*), Sec. 113.

125 *g.* LOAD LOSSES. See Measurement of Losses (*I*), Sec. 114.

126 NOTE. *b* and *c* are losses in the armature or "armature losses"; *d* and *e* "commutator losses"; *f* "field losses."

(*B*) ALTERNATING-CURRENT COMMUTATING MACHINES.

127 In ALTERNATING-CURRENT COMMUTATING MACHINES, the losses are:

128 *a.* BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

129 *b.* ROTATION LOSS, measured with the machine at open circuit, the brushes on the commutator, and the field excited by alternating current when driving the machine by a motor.

130 This loss includes molecular magnetic friction, and eddy currents, caused by rotation through the magnetic field, I^2r losses in cross-connections of cross-connected armatures, I^2r and other losses in armature-coils and armature-leads which are short-circuited by the brushes as far as these losses are due to rotation.

131 *c.* ALTERNATING or TRANSFORMER LOSS. These losses are measured by wattmeter in the field circuit, under the conditions of test *b*. They include molecular magnetic friction and eddy-currents due to the alternation of the magnetic field, I^2r losses in cross-connections of cross-connected armatures, I^2r and other losses in armature coil and commutator leads which are short-circuited by the brushes, as far as these losses are due to the alternation of the magnetic flux.

132 The losses in armature-coils and commutator leads short-circuited by the brushes, can be separated in *b*, and *c*, from the other losses, by running the machine with and without brushes on the commutator.

133 *d.* I^2r LOSS, OTHER LOAD LOSSES in armature and compensating winding and I^2r loss of brushes, measured by wattmeter connected across the armature and compensating winding.

134 *e.* FIELD EXCITATION LOSS. See Measurement of Losses (*H*). Sec. 113.

135 *f.* COMMUTATOR BRUSH-FRICTION. See Measurement of Losses (*B*), Sec. 103.

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(C) SYNCHRONOUS COMMUTATING MACHINES.

136 1. In DOUBLE-CURRENT GENERATORS, the efficiency of the machine should be determined as a direct-current generator, and also as an alternating-current generator. The two values of efficiency may be different, and should be clearly distinguished.

137 2. In CONVERTERS the losses should be determined when driving the machine by a motor. These losses are:

138 *a*. BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

139 *b*. MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of losses (D) Sec. 105.

140 *c*. ARMATURE RESISTANCE LOSS. This loss in the armature is $q I^2 r$, where I = direct current in armature, r = armature resistance and q, a factor which is equal to 1.47 in single-circuit single-phase, 1.15 in double-circuit single-phase, 0.59 in three-phase, 0.39 in two-phase, and 0.27 in six-phase converters.

141 *d*. COMMUTATOR-BRUSH FRICTION. See Measurement of Losses (*B*), Sec. 103.

142 *e*. COLLECTOR-RING BRUSH FRICTION. See Measurement of Losses (*C*), Sec. 104.

143 *f*. COMMUTATOR-BRUSH AND BRUSH-CONTACT RESISTANCE LOSS. See Measurement of Losses (*F*), Sec. 111.

144 *g*. COLLECTOR-RING BRUSH-CONTACT RESISTANCE LOSS. See Measurement of Losses (*G*), Sec. 112.

145 *h*. FIELD EXCITATION LOSS. See Measurement of Losses (*H*), Sec. 109.

146 *i*. LOAD LOSSES. These can generally be neglected, owing to the absence of field distortion.

147 3. THE EFFICIENCY OF TWO SIMILAR CONVERTERS may be determined by operating one machine as a converter from direct to alternating, and the other as a converter from alternating to direct, connecting the alternating sides together, and measuring the difference between the direct-current input, and the direct-current output. This process may be modified by returning the output of the second machine through two boosters into the first machine and measuring the losses. Another modification is to supply the losses by an alternator between the two machines, using potential regulators.

(D) SYNCHRONOUS MACHINES.

148 In SYNCHRONOUS MACHINES the losses are:

149 *a*. BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

150 *b*. MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of Lossess (*D*), Sec. 105.

151 *c*. ARMATURE RESISTANCE LOSS. See Measurement of Losses (*E*) Sec. 110.

152 *d*. COLLECTOR-RING BRUSH FRICTION. See Measurement of Losses (*C*), Sec. 104.

153 *e*. COLLECTOR-RING BRUSH CONTACT RESISTANCE LOSS. See Measurement of Losses (*G*), Sec. 112.

154 *f* FIELD EXCITATION LOSS. See Measurement of Losses (*H*), Sec. 113.

155 *g*. LOAD LOSSES. See Measurement of Losses (*I*), Sec. 114.

(E) STATIONARY INDUCTION APPARATUS.

156 In STATIONARY INDUCTION APPARATUS, the losses are:

157 *a* MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS measured at open secondary circuit, rated frequency, and at rated voltage — $I r$, where I = rated current, r = resistance of primary circuit.

158 *b*. RESISTANCE LOSSES, the sum of the $I^2 r$ losses in the primary and in the secondary windings of a transformer, or in the two sections of the coil in a compensator or auto-transformer, where I = rated current in the coil or section of coil, and r = resistance.

159 *c*. LOAD LOSSES, *i.e.*, eddy currents in the iron and especially in the copper conductors, caused by the current at rated load. For practical

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purposes they may be determined by short-circuiting the secondary of the transformer and impressing upon the primary a voltage sufficient to send rated load current through the transformer. The loss in the transformer under these conditions measured by wattmeter gives the load losses + $I^2 r$ losses in both primary and secondary coils.

160 In Closed Magnetic Circuit Transformers, either of the two circuits may be used as primary when determining the efficiency.

161 In Potential Regulators, the efficiency should be taken at the maximum voltage for which the apparatus is designed, and with non-inductive load, unless otherwise specified.

(*F*) Rotary Induction Apparatus, or Induction Machines.

162 In Rotary Induction Apparatus, the losses are:

163 *a.* Bearing Friction and Windage. See Measurement of Losses (*A*), Sec. 102.

164 *b.* Molecular Magnetic Friction and Eddy Currents in iron, copper and other metallic parts; also $I^2 r$ losses which may exist in multiple-circuit windings. *a* and *b* together are determined by running the motor without load at rated voltage, and measuring the power input.

165 *c.* Primary $I^2 R$ Loss, which may be determined by measurement of the current and the resistance.

166 *d.* Secondary $I^2 R$ Loss, which may be determined as in the primary, when feasible; otherwise, as in squirrel-cage secondaries, this loss is measured as part of *e*.

167 *e.* Load Losses; *i.e.*, molecular magnetic friction, and eddy currents in iron, copper, etc., caused by the stray field of primary and secondary currents, and secondary $I^2 R$ loss when undeterminable under (*d*). These losses may for practical purposes be determined by measuring the total power, with the rotor short-circuited at standstill and a current in the primary circuit equal to the primary energy current at full load. The loss in the motor under these conditions may be assumed to be equal to the load losses $+ I^2 r$ losses in both primary and secondary coils.

(*G*) Unipolar or Acyclic Machines.

168 In Unipolar Machines, the losses are:

169 (*a*) Bearing Friction and Windage. See Measurement of Losses (*A*), Sec. 102.

170 (*b*) Molecular Magnetic Friction and Eddy Currents. See Measurement of Losses (*E*), Sec. 106.

171 (*c*) Armature Resistance Losses. See Measurement of Losses (*E*), Sec. 110.

172 (*d*) Collector Brush Friction. See Measurement of Losses (*C*), Sec. 104.

173 (*e*) Collector Brush Contact Resistance. See Measurement of Losses (*G*), Sec. 112.

174 (*f*) Field-Excitation as in Sec. 113. See Measurement of Losses (*H*), Sec. 113.

175 (*g*) Load Losses. See Measurement of Losses (*I*), Sec. 114.

(*H*) Rectifying Apparatus, Pulsating-Current Generators.

176 This Division Includes: open-coil arc machines and mechanical and other rectifiers.

177 In Rectifiers the most satisfactory method of determining the efficiency is to measure both electric input and electric output by wattmeter. The input is usually inductive, owing to phase displacement and to wave distortion. For this reason the power factor and the apparent efficiency should also be considered, since the latter may be much lower than the true efficiency. The power consumed by auxiliary devices, such as the synchronous motor or cooling devices, should be included in the electric input.

178 In Constant-Current Rectifiers, transforming from constant potential alternating to constant direct current, by means of constant-current transforming devices and rectifying devices, the losses in the transforming devices are to be included in determining the efficiency and have to be

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measured when operating the rectifier, since in this case the losses may be greater than when feeding an alternating secondary circuit. In constant-current transforming devices, the load losses may be considerable, and, therefore, should not be neglected.

179 In OPEN COIL ARC MACHINES, the losses are essentially the same as in direct-current (closed coil) commutating machines. In this case, however, the load losses are usually greater, and the efficiency should preferably be measured by input- and output-test, using wattmeters for measuring the output. In alternating-current rectifiers, the output should, in general, be measured by wattmeter and not by voltmeter and ammeter, since owing to pulsation of current and voltage, a considerable discrepancy may exist between watts and volt-amperes. If, however, a direct-current and an alternating-current meter in the rectified circuit (either a voltmeter or an ammeter) give the same reading, the output may be measured by direct-current voltmeter and ammeter. The type of alternating-current instrument here referred to should indicate the effective or root-of-mean-square value and the type of direct-current instrument the arithmetical mean value, which would be zero on an alternating-current circuit.

(*I*) TRANSMISSION LINES.

180 The EFFICIENCY of transmission lines should be measured with non-inductive load at the receiving end, with the rated receiving voltage and frequency, also with sinusoidal impressed wave form, except where expressly specified otherwise, and with the exclusion of transformers or other apparatus at the ends of the line.

(*J*) PHASE-DISPLACING APPARATUS.

181 In APPARATUS PRODUCING PHASE DISPLACEMENT as, for example, synchronous compensators, exciters of induction generators, reactors, condensers, polarization cells, etc., the efficiency should be understood to be the ratio of the volt-amperes minus power loss to the volt-amperes.

182 The EFFICIENCY may be calculated by determining the losses, subtracting them from the volt-amperes, and then dividing the difference by the volt-amperes.

183 In SYNCHRONOUS COMPENSATORS and exciters of induction generators, the determination of losses is the same as in other synchronous machines.

184 In REACTORS the losses are molecular magnetic friction, eddy losses and $I^2 r$ loss. They should be measured by wattmeter. The efficiency of reactors should be determined with a sine wave of impressed voltage except where expressly specified otherwise.

185 In CONDENSERS, the losses are due to dielectic hysteresis and leakage, and should be determined by wattmeter with a sine wave of voltage.

186 In POLARIZATION CELLS, the losses are those due to electric resistivity and a loss in the electrolyte of the nature of chemical hysteresis. These losses may be considerable. They depend upon the frequency, voltage and temperature, and should be determined with a sine wave of impressed voltage, except where expressly specified otherwise.

D. REGULATION.

(I) *DEFINITIONS.*

187 DEFINITION. The regulation of a machine or apparatus in regard to some characteristic quantity (such as terminal voltage, current or speed) is the ratio of the deviation of that quantity from its normal value at rated load to the normal rated load value. The term "regulation," therefore, has the same meaning as the term "inherent regulation," occasionally used.

188 CONSTANT STANDARD. If the characteristic quantity is intended to remain constant (*e.g.*, constant voltage, constant speed, etc.) between rated load and no load, the regulation is the ratio of the maximum variation from the rated load value to the no-load value.

189 VARYING STANDARD. If the characteristic quantity is intended to vary in a definite manner between rated load and no load, the regulation is the ratio of the maximum variation from the specified condition to the normal rated-load value.

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190 (*a*) NOTE. If the law of the variation (in voltage, current, speed, etc.) between rated load and no load is not specified, it should be assumed to be a simple linear relation; *i.e.*, one undergoing uniform variation between rated load and no load.

191 (*b*) NOTE. The regulation of an apparatus may, therefore, differ according to its qualification for use. Thus, the regulation of a compound-wound generator specified as a constant-potential generator, will be different from that which it possesses when specified as an over-compounded generator.

192 In CONSTANT-POTENTIAL MACHINES, the regulation is the ratio of the maximum difference of terminal voltage from the rated-load value (occurring within the range from rated load to open circuit) to the rated load terminal voltage.

193 In CONSTANT-CURRENT MACHINES, the regulation is the ratio of the maximum difference of current from the rated load value (occurring within the range from rated-load to short-circuit, or minimum limit of operation), to the rated-load current.

194 In CONSTANT-POWER APPARATUS, the regulation is the ratio of maximum difference of power from the rated load value (occurring within the range of operation specified) to the rated power.

195 In CONSTANT-SPEED DIRECT-CURRENT MOTORS and INDUCTION MOTORS the regulation is the ratio of the maximum variation of speed from its rated load value (occurring within the range from rated load to no-load) to the rated load speed.

196 The regulation of an induction motor is, therefore, not identical with the slip of the motor, which is the ratio of the drop in speed from synchronism, to the synchronous speed.

197 In CONSTANT-POTENTIAL TRANSFORMERS, the regulation is the ratio of the rise of secondary terminal voltage from rated non-inductive load to no-load (at constant primary impressed terminal voltage) to the secondary terminal voltage at rated load.

198 In OVER-COMPOUNDED MACHINES, the regulation is the ratio of the maximum difference in voltage from a straight line connecting the no-load and rated-load values of terminal voltage as function of the load current, to the rated-load terminal voltage.

199 In CONVERTERS, DYNAMOTORS, MOTOR-GENERATORS AND FREQUENCY CONVERTERS, the regulation is the ratio of the maximum difference of terminal voltage at the output side from the rated-load voltage, to the rated-load voltage on the output side.

200 In TRANSMISSION LINES, FEEDERS, ETC., the regulation is the ratio of the maximum voltage difference at the receiving end, between rated non-inductive load and no load to the rated-load voltage at the receiving end (with constant voltage impressed upon the sending end).

201 In STEAM ENGINES, the regulation is the ratio of the maximum variation of speed in passing slowly from rated-load to no-load (with constant steam pressure at the throttle) to the rated-load speed. For variation and pulsation see Secs. 59-64.

202 In a HYDRAULIC TURBINE or OTHER WATER-MOTOR, the regulation is the ratio of the maximum variation of speed in passing slowly from rated-load to no-load (at constant head of water; *i.e.*, at constant difference of level between tail race and head race), to the rated-load speed. For variation and pulsation see Secs. 59-64.

203 In a GENERATOR-UNIT, consisting of a generator united with a prime-mover, the regulation should be determined at constant conditions of the prime-mover; *i.e.*, constant steam pressure, head, etc. It includes the inherent speed variations of the prime-mover. For this reason the regulation of a generator-unit is to be distinguished from the regulation of either the prime mover, or of the generator contained in it, when taken separately.

(II) *CONDITIONS FOR AND TESTS OF REGULATION.*

204 SPEED. The REGULATION OF GENERATORS is to be determined at constant speed, and of alternating apparatus at constant impressed frequency.

205 NON-INDUCTIVE LOAD. In apparatus generating, transforming or trans-

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mitting alternating currents, regulation should be understood to refer to non-inductive load, that is, to a load in which the current is in phase with the e.m.f. at the output side of the apparatus, except where expressly specified otherwise.

206 Wave Form. In alternating apparatus receiving electric power, regulation should refer to a sine wave of e.m.f., except where expressly specified otherwise.

207 Excitation. In commutating machines, rectifying machines, and synchronous machines, such as direct-current generators and motors, alternating-current and polyphase generators, the regulation is to be determined under the following conditions:

(1) At constant excitation in separately excited fields.

(2) With constant resistance in shunt-field circuits, and

(3) With constant resistance shunting series-field circuits; *i.e.*, the field adjustment should remain constant, and should be so chosen as to give the required full-load voltage at full-load current.

208 Impedance Ratio. In alternating-current apparatus, in addition to the non-inductive regulation, the impedance ratio of the apparatus should be specified; *i.e.*, the ratio of the voltage consumed by the total internal impedance of the apparatus at full-load current, to its rated full-load voltage. As far as possible, a sinusoidal current should be used.

209 Computation of Regulation. When in synchronous machines the regulation is computed from the terminal voltage and impedance voltage, the exciting ampere-turns corresponding to terminal voltage plus armature-resistance-drop, and the ampere-turns at short-circuit corresponding to the armature-impedance-drop, should be combined vectorially to obtain the resultant ampere-turns, and the corresponding internal e.m.f. should be taken from the saturation curve.

E. INSULATION.

(I) *INSULATION RESISTANCE.*

210 Insulation Resistance is the ohmic resistance offered by an insulating coating, cover, material or support to an impressed voltage, tending to produce a leakage of current through the same.

211 Ohmic Resistance and Dielectric Strength. The ohmic resistance of the insulation is of secondary importance only, as compared with the dielectric strength, or resistance to rupture by high voltage. Since the ohmic resistance of the insulation can be very greatly increased by baking, but the dielectric strength is liable to be weakened thereby, it is preferable to specify a high dielectric strength rather than a high insulation resistance. The high-voltage test for dielectric strength should always be applied.

212 Recommended Value of Resistance. The insulation resistance of complete apparatus should be such that the rated voltage of the apparatus will not send more than $\frac{1}{1{,}000{,}000}$ of the rated-load current, at the rated terminal voltage, through the insulation. Where the value found in this way exceeds 1 megohm, it is usually sufficient.

213 Insulation Resistance Tests should, if possible, be made at the pressure for which the apparatus is designed.

(II) *DIELECTRIC STRENGTH.*

(A) Test Voltages.

214 Definition. The dielectric strength of an insulating wall, coating, cover or path is measured by the voltage which must be applied to it in order to effect a disruptive discharge through the same.

215 Basis for Determining Test Voltages. The test voltage which should be applied to determine the suitability of insulation for commercial operation is dependent upon the kind and size of the apparatus and its normal operating voltage, upon the nature of the service in which it is to be used, and the severity of the mechanical and electrical stresses to

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which it may be subjected. The voltages and other conditions of test which are recommended have been determined as reasonable and proper for the great majority of cases and are proposed for general adoption, except when specific reasons make a modification desirable.

216 CONDITION OF APPARATUS TO BE TESTED. Commercial tests should, in general, be made with the completely assembled apparatus and not with individual parts. The apparatus should be in good condition and high-voltage tests, unless otherwise specified, should be applied before the machine is put into commercial service, and should not be applied when the insulation resistance is low owing to dirt or moisture. High-voltage tests should, in general, be made at the temperature assumed under normal operation. High-voltage tests considerably in excess of the normal voltages to determine whether specifications are fulfilled are admissible on new machines only.

217 POINTS OF APPLICATION OF VOLTAGE. The test voltage should be successively applied between each electric circuit and all other electric circuits including conducting material in the apparatus.

218 The FREQUENCY of the alternating-current test voltage is, in general, immaterial within commercial ranges. When, however, the frequency has an appreciable effect, as in alternating-current apparatus of high voltage and considerable capacity, the rated frequency of the apparatus should be used.

219 TABLE OF TESTING VOLTAGES. The following voltages are recommended for testing all apparatus, lines and cables, by a continued application for one minute. The test should be with alternating voltage having an effective value (or root mean square referred to a sine wave of voltage) given in the table and preferably for tests of alternating apparatus at the normal frequency of the apparatus.

	Rated Terminal Voltage of Circuit.	Rated Output.	Testing Voltage.
220	Not exceeding 400 volts	Under 10 kw	1,000 volts.
	" " "	10 kw. and over	1,500 "
	400 and over, but less than 800 volts	Under 10 kw	1,500 "
	" " " " "	10 kw. and over	2,000 "
	800 " " " 1,200 "	Any	3,500 "
	1,200 " " " 2,500 "	Any	5,000 "
	2,500 " "	Any	Double the normal rated voltages.

221 EXCEPTION.—TRANSFORMERS. Transformers having primary pressures of from 550 to 5,000 volts, the secondaries of which are directly connected to consumption circuits, should have a testing voltage of 10,000 volts, to be applied between the primary and secondary windings, and also between the primary winding and the core.

222 EXCEPTION.—FIELD WINDINGS. The tests for field windings should be based on the rated voltage of the exciter and the rated output of the machine of which the coils are a part. Field windings of synchronous motors and converters, which are to be started by applying alternating current to the armature when the field is not excited and a high voltage is induced in the field windings, should be tested at 5,000 volts.

223 RATED TERMINAL VOLTAGE.—DEFINITION. The rated terminal voltage of circuit in the above table, means the voltage between the conductors of the circuit to which the apparatus to be tested is to be connected,—for instance, in three-phase circuits the delta voltage should be taken. In the following specific cases, the rated terminal voltage of the circuit is to be determined as specified in ascertaining the testing voltage:

224 (*a*) TRANSFORMERS. The test of the insulation between the primary and secondary windings of transformers, is to be the same as that between the high-voltage windings and core, and both tests should be made simultaneously by connecting the low-tension winding and core together during the test. If a voltage equal to the specified testing voltage be induced in the high-tension winding of a transformer it may be used for insulation tests instead of an independently induced voltage. These tests should be made first with one end and then with the other end of the high-tension winding connected to the low-tension winding and to the core.

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225 (*b*) Constant-Current Apparatus. The testing voltage is to be based upon a rated terminal voltage equal to the maximum voltage which may exist at open or closed circuit.

226 (*c*) Apparatus in Series. For tests of machines or apparatus to be operated in series, so as to employ the sum of their separate voltages the testing voltage is to be based upon a rated terminal voltage equal to the sum of the separate voltages except where the frames of the machines are separately insulated, both from the ground and from each other, in which case the test for insulation between machines should be based upon the voltage of one machine, and the test between each machine and ground to be based upon the total voltage of the series.

(*B*) Methods of Testing.

227 Classes of Tests. Tests for dielectric strength cover such a wide range in voltage that the apparatus, methods and precautions which are essential in certain cases do not apply to others. For convenience, the tests will be separated into two classes:

228 Class 1. This class includes all apparatus for which the test voltage deos not exceed 10 kilovolts, unless the apparatus is of very large static capacity, *e.g.*, a large cable system. This class also includes all apparatus of small static capacity, such as line insulators, switches and the like, for all test voltages.

229 Method of Test for Class 1. The test voltage is to be continuously applied for the prescribed interval,—(one minute unless otherwise specified). The test voltage may be taken from a constant-potential source and applied directly to the apparatus to be tested, or it may be raised gradually as specified for tests under Class 2.

230 Class 2. This class includes all apparatus not included in Class 1.

231 Method of Test for Class 2. The test voltage is to be raised to the required value smoothly and without sudden large increments and is then to be continuously applied for the prescribed interval,—(one minute, unless otherwise specified), and then gradually decreased.

232 Conditions and Precautions for Class 1 and Class 2. The following apply to all tests:

233 The Wave Shape should be approximately sinusoidal and the apparatus in the testing circuits should not materially distort this wave.

234 The Supply Circuit should have ample current-supply capacity so that the charging current which may be taken by the apparatus under test will not materially alter the wave form nor materially affect the test voltage. The circuit should be free from accidental interruptions.

235 Resistance or Inductance in series with the primary of a raising transformer for the purpose of controlling its voltage is liable seriously to affect the wave form, thereby causing the maximum value of the voltage to bear a different and unknown ratio to the root mean square value. This method of voltage adjustment is, therefore, in general, undesirable. It may be noted that if a resistance or inductance is employed to limit the current when burning out a fault, such resistance or inductance should be short circuited during the regular voltage test.

236 The Insulation under test should be in normal condition as to dryness and the temperature should when possible be that reached in normal service.

237 Additional Conditions and Precautions for Class 2. The following conditions and precautions, in addition to the foregoing, apply to tests of apparatus included in Class 2.

238 Sudden Increment of Testing Voltage on the apparatus under test should be avoided, particularly at high voltages and with apparatus having considerable capacity, as a momentarily excessive rise in testing voltage will result.

239 Sudden Variations in Testing Voltage of the circuit supplying the voltage during the test should be avoided as they are likely to set up injurious oscillation.

240 Good Connections in the circuits supplying the test voltage are essential in order to prevent injurious high frequency disturbances from being set up. When a heavy current is carried by a small water rheostat,

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arcing may occur, causing high-frequency disturbances which should be carefully avoided.

241 TRANSFORMER COILS. In high-tension transformers, the low-tension coil should preferably be connected to the core and to the ground when the high-tension test is being made, in order to avoid the stress from low-tension to core, which would otherwise result through condenser action. The various terminals of each winding of the high-tension transformer under test should be connected together during the test in order to prevent undue stress on the insulation between turns or sections of the winding in case the high-voltage test causes a break-down.

(*C*) METHODS FOR MEASURING THE TEST VOLTAGE.

242 FOR MEASURING THE TEST VOLTAGE, two instruments are in common use, (1) the spark gap and (2) the voltmeter.

243 1. THE SPARK GAP is ordinarily adjusted so that it will break down with a certain predetermined voltage, and is connected in parallel with the insulation under test. It ensures that the voltage applied to the insulation is not greater than the break-down voltage of the spark gap. A given setting of the spark gap is a measure of one definite voltage, and, as its operation depends upon the maximum value of the voltage wave, it is independent of wave form and is a limit on the maximum stress to which the insulation is subjected. The spark gap is not conveniently adapted for comparatively low voltages.

244 In SPARK-GAP MEASUREMENTS, the spark gap may be set for the required voltage and the auxiliary apparatus adjusted to give a voltage at which this spark gap just breaks down. The spark gap should then be adjusted for, say, 10 per cent. higher voltage, and the auxiliary apparatus again adjusted to give the voltage of the former breakdown, which is to be the assumed voltage for the test. This voltage is to be maintained for the required interval.

245 The SPARK POINTS should consist of new sewing needles, supported axially at the ends of linear conductors which are each at least twice the length of the gap. There should be no extraneous body near the gap within a radius of twice its length. A table of approximate striking distances is given in Appendix D. This table should be used in connection with tests made by the spark-gap methods.

246 A NON-INDUCTIVE RESISTANCE of about one-half ohm per volt should be inserted in series with each terminal of the gap so as to keep the discharge current between the limits of one-quarter ampere and 2 amperes. The purpose of the resistance is to limit the current in order to prevent the surges which might otherwise occur at the time of break-down.

247 2. The VOLTMETER gives a direct reading, and the different values of the voltage can be read during the application and duration of the test. It is suitable for all voltages, and does not introduce disturbances into the test circuit.

248 In VOLTMETER MEASUREMENTS, the voltmeter should, in general, derive its voltage from the high-tension testing circuit either directly or through an auxiliary ratio transformer. It is permissible, however, to measure the voltage at other places,—for example, on the primary of the transformer, provided the ratio of transformation does not materially vary during the test; or that proper account is taken thereof.

249 SPARK GAP AND VOLTMETER. The spark gap may be employed as a check upon the voltmeter used in high-tension tests in order to determine the transformation ratio of the transformer, the variation from the sine wave form and the like. It is also useful in conjunction with voltmeter measurements to limit the stress applied to the insulating material.

(*D*) APPARATUS FOR SUPPLYING TEST VOLTAGE.

250 The GENERATOR OR CIRCUIT supplying voltage for the test should have ample current carrying capacity, so that the current which may be taken for charging the apparatus to be tested will not materially alter the wave form nor otherwise materially change the voltage.

The TESTING TRANSFORMER should be such that its ratio of transformation does not vary more than 10 per cent. when delivering the charg-

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ing current required by the apparatus under test. (This may be determined by short-circuiting the secondary or high voltage winding testing transformer and supplying 1/10 of the primary voltage to the primary under this condition. The primary current that flows under this condition is the maximum which should be permitted in regular dielectric tests.)

251 The VOLTAGE CONTROL may be secured in either of several ways, which, in order of preference, are as follows:

252 1. By generator field circuit.

253 2. By magnetic commutation.

254 3. By change in transformer ratio.

255 4. By resistance or choke coils.

256 In GENERATOR VOLTAGE CONTROL, the voltage of the generator should preferably be about its approximate normal rated-load value when the full testing voltage is attained, which requires that the ratio of the raising transformer be such that the full testing voltage is reached when the generator voltage is normal. This avoids the instability in the generator which may occur if a considerable leading current is taken from it when it has low voltage and low field current.

257 In MAGNETIC COMMUTATION, the control is effected by shunting the magnetic flux through a secondary coil so as to vary the induction through the coil and the voltage induced in it. The shunting should be effected smoothly, thus avoiding sudden changes in the induced voltage.

258 In TRANSFORMER VOLTAGE CONTROL, by change of ratio, it is necessary that the transition from one step to another be made without interruption of the test voltage, and by steps sufficiently small to prevent surges in the testing circuit. The necessity of this precaution is greater as the inductance or the static capacity of the apparatus in the testing circuit under test is greater.

259 When RESISTANCE COILS OR REACTORS are used for voltage control, it is desirable that the testing voltage should be secured when the controlling resistance or reactance is very nearly or entirely out of circuit in order that the disturbing effect upon the wave form which results may be negligible at the highest voltage.

F. CONDUCTIVITY.

260 COPPER. The conductivity of copper in electric wires and cables should not be less than 98% of Matthiessen's standard of conductivity, as defined in the Copper Wire Table of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

G. RISE OF TEMPERATURE.

(I) *MEASUREMENT OF TEMPERATURE.*

(A) METHODS.

261 There are two methods in common use for determining the rise in temperature, viz.: (1) by thermometer, and (2) by increase in resistance of an electric circuit.

262 1. By THERMOMETER. The following precautions should be observed in the use of thermometers:

263 *a*. PROTECTION. The thermometers indicating the room temperature should be protected from thermal radiation emitted by heated bodies, or from draughts of air or from temporary fluctuations of temperature. Several room thermometers should be used. In using the thermometer by applying it to a heated part, care should be taken so to protect its bulb as to prevent radiation from it, and, at the same time, not to interfere seriously with the normal radiation from the part to which it is applied.

264 *b*. BULB. When a thermometer is applied to the free surface of a machine, it is desirable that the bulb of the thermometer should be covered by a pad of definite area. A convenient pad may be formed of cotton waste in a shallow circular box about one and a half inches in diameter, through a slot in the side in which the thermometer bulb is inserted. An unduly large pad over the thermometer tends to interfere with the natural liberation of heat from the surface to which the thermometer is applied.

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265 2. By INCREASE IN RESISTANCE. The resistance may be measured either by Wheatstone bridge, or by drop-of potential method. A temperature coefficient of 0.42 per cent. per degree C., from and at 0° C., may be assumed for copper.

The temperature-coefficients from and at each degree cent. between 0° C. and 50° C. are given in Appendix E. The temperature rise may be determined either (1) by dividing the percentage increase of initial resistance by the temperature-coefficient for the initial temperature expressed in per cent.; or (2) by multiplying the increase in per cent. of the initial resistance by 238.1 plus the initial temperature in degrees C., and then dividing the product by 100.

266 3. COMPARISON OF METHODS. In electrical conductors, the rise of temperature should be determined by their increase of resistance where practicable. Temperature elevations measured in this way are usually in excess of temperature elevations measured by thermometers. In very low resistance circuits, thermometer measurements are frequently more reliable than measurements by the resistance method. Where a thermometer applied to a coil or winding, indicates a higher temperature elevation than that shown by resistance measurement, the thermometer indication should be accepted.

(*B*) NORMAL CONDITIONS FOR TESTS.

267 1. DURATION OF TESTS. The temperature should be measured after a run of sufficient duration for the apparatus to reach a practically constant temperature. This is usually from 6 to 18 hours, according to the size and construction of the apparatus. It is permissible, however, to shorten the time of the test by running a lesser time on an overload in current and voltage, then reducing the load to normal, and maintaining it thus until the temperature has become constant.

268 2. ROOM TEMPERATURE. The rise of temperature should be referred to the standard condition of a room temperature of 25° C.

269 TEMPERATURE CORRECTION. If the room temperature during the test differs from 25° C., correction on account of difference in resistance should be made by changing the observed rise of temperature by one-half per cent. for each degree C. Thus with a room temperature of 35° C., the observed rise of temperature has to be decreased by 5 per cent., and with a room temperature of 15° C., the observed rise of temperature has to be increased by 5 per cent. In certain cases, such as shunt-field circuits without rheostat, the current strength will be changed by a change of room temperature. The heat-production and dissipation may be thereby affected. Correction for this should be made by changing the observed rise in temperature in proportion as the $I^2 R$ loss in the resistance of the apparatus is altered owing to the difference in room temperature.

270 3. BAROMETRIC PRESSURE. VENTILATION. A barometric pressure of 760 mm. and normal conditions of ventilation should be considered as standard, and the apparatus under test should neither be exposed to draught nor enclosed, except where expressly specified. The barometric pressure needs to be considered only when differing greatly from 760 mm.

271 BAROMETRIC PRESSURE CORRECTION. When the barometric pressure differs greatly from the standard pressure of 760 mm. of mercury, as at high altitudes, a correction should be applied. In the absence of more accurate data, a correction of 1% of the observed rise in temperature for each 10 mm. deviation from the 760 m.m. standard is recommended. For example at a barometric pressure of 680 mm. the observed rise of temperature is to be reduced by $\frac{760-680}{10} = 8\%$.

(II) *LIMITING TEMPERATURE RISE.*

272 GENERAL. The temperature of electrical machinery under regular service conditions, should never be allowed to remain at a point at which permanent deterioration of its insulating material takes place.

273 LIMITS RECOMMENDED. It is recommended that the following maximum

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values of temperature elevation, referred to a standard room temperature of 25 degrees centigrade, at rated load under normal conditions of ventilation or cooling, should not be exceeded.

(*A*) Machines in General.

274 In commutating machines, rectifying machines, pulsating-current generators, synchronous machines, synchronous commutating machines and unipolar machines, the temperature rise in the parts specified should not exceed the following:

275 Field and armature, 50° C.

276 Commutator and brushes, by thermometer, 55° C.

277 Collector rings, 65° C.

278 Bearings and other parts of machine, by thermometer, 40° C.

279 (*B*) Rotary Induction Apparatus. The temperature rise should not exceed the following:

280 Electric circuits, 50° C., by resistance.

281 Bearings and other parts of the machine 40° C., by thermometer.

282 In squirrel-cage or short-circuited armatures, 55° C., by thermometer, may be allowed.

(*C*) Stationary Induction Apparatus.

283 *a*. Transformers for Continuous Service. The temperature rise should not exceed 50 degrees centigrade in electric circuits, by resistance; and in other parts, by thermometer.

284 *b*. Transformers for Intermittent Service. In the case of transformers intended for intermittent service, or not operating continuously at rated load, but continuously in circuit, as in the ordinary case of lighting transformers, the temperature elevation above the surrounding air-temperature should not exceed 50° C., by resistance in electric circuits and by thermometer in other parts, after the period corresponding to the term of rated load. In this instance, the test load should not be applied until the transformer has been in circuit for a sufficient time to attain the temperature elevation due to core loss. With transformers for commercial lighting, the duration of the rated-load test may be taken as three hours, unless otherwise specified.

285 *c*. Reactors, induction- and magneto-regulators—electric circuits by resistance and other parts by thermometer, 50° C.

286 *a*. Large Apparatus. Large generators, motors, transformers, or other apparatus in which reliability and reserve overload capacity are important, are frequently specified not to rise in temperature more than 40 degrees centigrade under rated load and 55 degrees centigrade at rated overload. It is, however, ordinarily undesirable to specify lower temperature elevations than 40 degrees centigrade at rated load, measured as above.

(*D*) Rheostats.

287 In Rheostats, Heaters and other electrothermal apparatus, no combustible or inflammable part or material, or portion liable to come in contact with such material, should rise more than 50° C. above the surrounding air under the service conditions for which it is designed.

288 *a*. Parts of Rheostats. Parts of rheostats and similar apparatus rising in temperature, under the specified service conditions, more than 50° C., should not contain any combustible material, and should be arranged or installed in such a manner that neither they, nor the hot air issuing from them, can come in contact with combustible material.

(*E*) Limits Recommended in Special Cases.

289 *a*. Heat Resisting Insulation. With apparatus in which the insulating materials have special heat-resisting qualities, a higher temperature elevation is permissible.

290 *b*. High Air Temperature. In apparatus intended for service in places of abnormally high temperature, a lower temperature elevation should be specified.

291 *c*. Apparatus Subject to Overload. In apparatus which by the nature of its service may be exposed to overload, or is to be used in very high voltage circuits, a smaller rise of temperature is desirable than in apparatus not liable to overloads or in low-voltage apparatus. In apparatus built for conditions of limited space, as railway motors, a higher rise of temperature must be allowed.

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292 *d.* Apparatus for Intermittent Service. In the case of apparatus intended for intermittent service, except railway motors, the temperature elevation which is attained at the end of the period corresponding to the term of rated load, should not exceed the values specified for machines in general. In such apparatus the temperature elevation, including railway motors, should be measured after operation, under as nearly as possible the conditions of service for which the apparatus is intended, and the conditions of the test should be specified.

H. OVERLOAD CAPACITIES.

293 Performance with Overload. All apparatus should be able to carry the overload hereinafter specified without serious injury by heating, sparking, mechanical weakness, etc., and with an additional temperature rise not exceeding 15° C., above those specified for rated loads, the overload being applied after the apparatus has acquired the temperature corresponding to rated load continuous operation. Rheostats to which no temperature rise limits are attached are naturally exempt from this additional temperature rise of 15° C. under overload specified in these rules.

294 Normal Conditions. Overload guarantees should refer to normal conditions of operation regarding speed, frequency, voltage, etc., and to non-inductive conditions in alternating apparatus, except where a phase displacement is inherent in the apparatus.

295 Overload Capacities Recommended. The following overload capacities are recommended:

296 *a.* Generators. Direct-current generators and alternating-current generators, 25 per cent. for two hours.

297 *b.* Motors. Direct-current motors, induction motors and synchronous motors, not including railway and other motors intended for intermittent service, 25 per cent. for two hours, and 50 per cent. for one minute.

298 *c.* Converters. Synchronous converters, 25 per cent. for two hours, 50 per cent. for one-half hour.

299 *d.* Transformers and Rectifiers. Constant-potential transformers and rectifiers, 25 per cent. for two hours; except in transformers connected to apparatus for which a different overload is guaranteed, in which case the same guarantees shall apply for the transformers as for the apparatus connected thereto.

300 *e.* Exciters. Exciters of alternators and other synchronous machines, 10 per cent. more overload than is required for the excitation of the synchronous machine at its guaranteed overload, and for the same period of time. All exciters of alternating-current, single-phase or polyphase generators should be able to give at its rated speed, sufficient voltage and current to excite the alternator, at the rated speed, to the full-load terminal voltage, at the rated output in kilovolt-amperes and with 50 per cent. power factor.

301 *f.* A Continuous-Service Rheostat, such as an armature- or field-regulating rheostat, should be capable of carrying without injury for two hours, a current 25 per cent. greater than that at which it is rated. It should also be capable of carrying for one minute a current 50 per cent. greater than its rated load current, without injury. This excess of capacity is intended for testing purposes only, and this margin of capacity should not be relied upon in the selection of the rheostat.

302 *g.* An Intermittent Service or Motor-starting Rheostat is used for starting a motor from rest and accelerating it to rated speed. Under ordinary conditions of service, and unless expressly stated otherwise, a motor is assumed to start in fifteen seconds and with 150% of rated current strength. A motor-starter should be capable of starting the motor under these conditions once every four minutes for one hour.

303 (*a*) This Test may be carried out either by starting the motor at four-minute intervals, or by placing the starter at normal temperature across the maximum voltage for which it is marked, and moving the lever uniformly and gradually from the first to the last position during a period of fifteen seconds, the current being maintained substantially constant at said 50% excess by introducing resistance in series or by other suitable means.

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304 (*b*) OTHER RHEOSTATS FOR INTERMITTENT-SERVICE are employed under such special and varied conditions, that no general rules are applicable to them.

III. VOLTAGES AND FREQUENCIES.

A. VOLTAGES.

305 DIRECT-CURRENT GENERATORS. In direct-current, low-voltage generators, the following average terminal voltages are in general use and are recommended:

125 volts. 250 volts. 550 to 600 volts.

306 LOW-VOLTAGE CIRCUITS. In direct-current and alternating-current low-voltage circuits, the following average terminal voltages are in general use and are recommended:

110 volts. 220 volts.

307 PRIMARY DISTRIBUTION CIRCUITS. In alternating-current, constant-potential, primary-distribution circuits, an average voltage of 2,200 volts, with step-down transformer ratios 1/10 and 1/20, is in general use, and is recommended.

308 TRANSMISSION CIRCUITS. In alternating-current constant-potential transmission circuits, the following average voltages are recommended.

6,600 11,000 22,000 33,000 44,000 66,000 88,000

309 TRANSFORMER RATIO. It is recommended that the standard transformer ratios should be such as to transform between the standard voltages above named. The ratio will, therefore, usually be an exact multiple of 5 or 10, *e. g.*, 2,200 to 11,000; 2,200 to 44,000.

310 RANGE IN VOLTAGE. In alternating-current generators, or generating systems, a range of terminal voltage should be provided from rated voltage at no load to 10 per cent. in excess thereof, to cover drop in transmission. If a greater range than ten per cent. is specified, the generator should be considered as special.

B. FREQUENCIES.

311 In ALTERNATING-CURRENT CIRCUITS, the following frequencies are, standard:

25∼ 60∼

312 These frequencies are already in extensive use and it is deemed advisable to adhere to them as closely as possible.

IV. GENERAL RECOMMENDATIONS.

313 NAME PLATES. All electrical apparatus should be provided with a name plate giving the manufacturer's name, the voltage and the current in amperes for which it is designed. Where practicable, the kilowatt capacity, character of current, speed, frequency, type, designation and serial number should be added.

314 DIAGRAMS OF CONNECTIONS. All electrical apparatus when leaving the factory should be accompanied by a diagram showing the electrical connections and the relation of the different parts in sufficient detail to give the necessary information for proper installation.

315 RHEOSTAT DATA. Every rheostat should be clearly and permanently marked with the voltage and amperes, or range of amperes, for which it is designed.

316 COLORED INDICATING LIGHTS. When using colored indicating lights on switch-boards, red should denote danger such as "switch closed," or "circuit alive"; green should denote safety, such as "switch open," or "circuit dead."

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317 When white lights are used a light turned on should denote danger, such as "switch closed" or "circuit alive"; while the light out should denote safety, such as "switch open," or "circuit dead." Low-efficiency lamps should be used.

318 The use of colored lights is recommended, as safer than white lights.

319 GROUNDING METAL WORK. It is desirable that all metal work near high potential circuits be grounded.

320 CIRCUIT OPENING DEVICES. The following definitions are recommended.

321 *a*. A CIRCUIT-BREAKER is an apparatus for breaking a circuit at the highest current which it may be called upon to carry.

322 *b*. A DISCONNECTING SWITCH is an apparatus designed to open a circuit only when carrying little or no current.

323 *c*. An AUTOMATIC CIRCUIT-BREAKER is an apparatus for breaking a circuit automatically under an excessive strength of current. It should be capable of breaking the circuit repeatedly at rated voltage and at the maximum current which it may be called upon to carry.

V. APPENDICES AND TABULAR DATA.

APPENDIX A. NOTATION.

The following notation is recommended:

324 E, e, voltage, e.m.f., potential difference
I, i, current
P, power
Φ, magnetic flux
$\mathfrak{B}$, B, magnetic density
R, r, resistance
x, reactance
Z, z, impedance
L, l, inductance
C, c, capacity
Y, y, admittance
b, susceptance
G, g, conductance

Vector quantities when used should be denoted by capital italics.

APPENDIX B.—RAILWAY MOTORS.

(I) *RATING.*

325 INTRODUCTORY NOTE ON RATING. Railway motors usually operate in a service in which both the speed and the torque developed by the motor are varying almost continually. The average requirements, however, during successive hours in a given class of service are fairly uniform. On account of the wide variation of the instantaneous loads, it is impracticable to assign any simple and definite rating to a motor which will indicate accurately the absolute capacity of a given motor or the relative capacity of different motors under service conditions. It is also impracticable to select a motor for a particular service without much fuller data with regard both to the motor and to the service than is required, for example, in the case of stationary motors which run at constant speeds.

326 SCOPE OF NOMINAL RATING. It is common usage to give railway motors a nominal rating in horse power on the basis of a one-hour test. As above explained, a simple rating of this kind is not a proper measure of service capacity. This nominal rating, however, indicates approximately the maximum output which the motor should ordinarily be called upon to develop during acceleration. Methods of determining the continuous capacity of a railway motor for service requirements are given under a subsequent heading.

327 The NOMINAL RATING of a railway motor is the horse-power output at the car-axle, that is, including gear and other transmission losses, which gives a rise of temperature above the surrounding air (referred to a room

temperature of 25 degrees cent.) not exceeding 90 degrees cent. at the commutator and 75 degrees Cent. at any other part after one hour's continuous run at its rated voltage (and frequency, in the case of an alternating-current motor) on a stand, with the motor-covers removed, and with natural ventilation. The rise in temperature is to be determined by thermometer, but the resistance of no electrical circuit in the motor shall increase more than 40% during the test.

(II) *SELECTION OF MOTOR FOR SPECIFIED SERVICE.*

328 GENERAL REQUIREMENTS. The suitability of a railway motor for a specified service depends upon the following considerations:

329 *a.* Mechanical ability to develop the requisite torque and speeds as given by its speed-torque curve.

330 *b.* Ability to commutate successfully the current demanded.

331 *c.* Ability to operate in service without occasioning a temperature rise in any part which will endanger the life of the insulation.

332 OPERATING CONDITIONS, TYPICAL RUN. The operating conditions which are important in the selection of a motor include the weight of load, the schedule speed, the distance between stops, the duration of stops, the rate of acceleration and of braking retardation, the grades and the curves. With these data at hand, the outputs which are required of the motor may be determined, provided the service requirements are within the limits of the speed-torque curve of the motor. These outputs may be expressed in the form of curves giving the instantaneous values of current and of voltage which must be applied to the motor. Such curves may be laid out for the entire line, but they are usually constructed only for a certain average or typical run, which is fairly representative of the conditions of service. To determine whether the motor has sufficient capacity to perform the service safely, further tests or investigations must be made.

333 CAPACITY TEST OF RAILWAY MOTOR IN SERVICE. The capacity of a railway motor to deliver the necessary output may be determined by measurement of its temperature after it has reached a maximum in service. If a running test cannot be made under the actual conditions of service, an equivalent test may be made in a typical run back and forth, under such conditions of schedule speed, length of run, rate of acceleration, etc., that the test cycle of motor losses and conditions of ventilation are essentially the same as would be obtained in the specified service.

334 METHODS OF COMPARING MOTOR CAPACITY WITH SERVICE REQUIREMENTS. Where it is not convenient to test motors under actual service conditions or in an equivalent typical run, recourse may be had to one of the two following methods of determining temperature rise now in general use:

335 1. METHOD BY LOSSES AND THERMAL CAPACITY CURVES. The heat developed in a railway motor is carried partly by conduction through the several parts and partly by convection through the air to the motor-frame whence it is distributed to the outside air. As the temperature of the several parts is thus dependent not only upon their own internal losses but also upon the temperature of neighboring parts, it becomes necessary to determine accurately the actual value and distribution of losses in a railway motor for a given service and reproduce them in an equivalent test-run The results of a series of typical runs expressed in the form of thermal capacity curves will give the relation between degrees rise per watt loss in the armature and in the field for all ratios of losses between them met with in the commercial application of a given motor.

336 This method consists, therefore, in calculating the several internal motor losses in a specified service and determining the temperature rise with these losses from thermal capacity curves giving the degrees rise per watt loss as obtained in experimental track tests made under the same conditions of ventilation.

337 The following motor losses cause its heating and should be carefully determined for a given service: $I^2 R$ in the field; $I^2 R$ in the armature; $I^2 R$ in the brush contacts, core loss and brush friction.

338 The loss in the bearings (in the case of geared motors) also adds somewhat to the motor-heating, but owing to the variable nature of such losses they are generally neglected in making calculations.

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339 2. Method by Continuous Capacity of Motor. The essential losses in the motor, as found in the typical run, are in most cases those in the motor windings and in the core. The mean service conditions may be expressed in terms of the current which would produce the same losses in the motor windings and the voltage which, with that current, would produce the same core losses as the average in service. The continuous capacity of the motor is given in terms of the amperes which it will carry when run on a testing stand—with covers on or off, as specified—at different voltages, say, 40, 60, 80 and 100 per cent. of the rated voltage—with a temperature rise not exceeding 90 degrees at the commutator and 75 degrees at any other part, provided the resistance of no electric circuit in the motor increases more than 40 per cent. A comparison of the equivalent service conditions with the continuous capacity of the motor will determine whether the service requirements are within the safe capacity of the motor.

340 This method affords a ready means of determining whether a specified service is within the capacity of a given motor and it is also a convenient approximate method for comparing the service capacities of different motors.

APPENDIX C. PHOTOMETRY AND LAMPS.

341 Candle-Power. The luminous intensity of sources of light is expressed in candle-power. The unit of candle-power should be derived from the standards maintained by the National Bureau of Standards at Washington, D. C., which standard unit of candle-power equals 100/88 of the Hefner unit under Reichsanstalt standard conditions for the Hefner. In practical measurements seasoned and carefully standardized incandescent lamps are more reliable and accurate than the primary standard.

342 Candle-Lumen. The total flux of light from a source is equal to its mean spherical intensity multiplied by 4π. The unit of flux is called the candle-lumen. A candle lumen is the $\frac{1}{4\pi}$th part of the total flux of light emitted by a source having a mean spherical intensity of one candle-power.

343 Candle-Meter. The unit of illumination is the candle-meter. This is the normal illumination produced by one unit of candle-power at a distance of one metre.

344 *a.* Candle-Foot. Illumination is occasionally expressed in candle-feet. A candle-foot is the normal illumination produced by one unit of candle-power at a distance of one foot.

345 1 candle-foot = 10.764 candle-metres.

The use of the candle-metre unit is preferable and is recommended.

346 The Efficiency of Electric Lamps is properly stated in terms of mean spherical candle-power per watt at lamp terminals. This use of the term efficiency is to be considered as special, and not to be confused with the generally accepted definition of efficiency in Sec. 85.

347 *a.* Efficiency, Auxiliary Devices. In illuminants requiring auxiliary power-consuming devices outside of the luminous body, such as steadying resistances in constant potential arc lamps, a distinction should be made between the net efficiency of the luminous source and the gross efficiency of the lamp. This distinction should always be stated. The gross efficiency should include the power consumed in the auxiliary resistance, etc. The net efficiency should, however, include the power consumed in the controlling mechanism of the lamp itself. Comparison between such sources of light should be made on the basis of gross efficiency, since the power consumed in the auxiliary device is essential to the operation.

348 *b.* A Standard Circuit Voltage of 110 volts, or a multiple thereof may be assumed, except where expressly stated otherwise.

349 Watts per Candle. The specific consumption of an electric lamp is its watt consumption per mean spherical candle-power. "Watts per candle" is the term used commercially in connection with incandescent lamps, and denotes, watts per mean horizontal candle-power.

350 Photometric Tests in which the results are stated in candle-power should always be made at such a distance from the source of light that

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the latter may be regarded as practically a point. Where tests are made at shorter distances, as for example in the measurement of lamps with reflectors, the results should always be given as "apparent candle-power" at the distance employed, which distance should always be specifically stated.

351 BASIS FOR COMPARISON. Either the total flux of light in candle-lumens, or the mean spherical candle-power, should always be used as the basis for comparing various luminous sources with each other, unless there is a clear understanding or statement to the contrary.

352 INCANDESCENT LAMPS, RATING. It is customary to rate incandescent lamps on the basis of their mean horizontal candle-power; but in comparing incandescent lamps in which the relative distribution of luminous intensity differs, the comparison should be based on their total flux of light measured in lumens, or on their mean spherical candle-power.

353 The SPHERICAL REDUCTION-FACTOR of a lamp

$$= \frac{\text{mean spherical candle-power}}{\text{mean horizontal candle-power}}$$

354 The TOTAL FLUX of light in candle-lumens emitted by a lamp $= 4\pi \times$ mean horizontal candle-power $\times$ spherical reduction-factor.

355 The SPHERICAL REDUCTION-FACTOR should only be used when properly determined for the particular type and characteristics of each lamp. The spherical reduction-factor permits of substantially accurate comparisons being made between the mean spherical candle-powers of different types of incandescent lamps, and may be used in the absence of proper facilities for direct measurement of mean spherical intensity.

356 "READING DISTANCE." Where standard photometric measurements are impracticable, approximate measurements of illuminants such as street lamps may be made by comparing their "reading distances;" *i.e.*, by determining alternately the distances at which an ordinary size of reading print can just be read, by the same person or persons, when all other light is screened. The angle below the horizontal at which the measurement is made should be specified when it exceeds 15°.

357 In COMPARING DIFFERENT LUMINOUS SOURCES not only should their candle-power be compared, but also their relative form, intrinsic brilliancy, distribution of illumination and character of light.

APPENDIX D. SPARKING DISTANCES.

358 Table of Sparking Distances in Air between Opposed Sharp Needle-Points, for Various Effective Sinusoidal Voltages, in inches and in centimetres. The table applies to the conditions specified in Secs. 240-246.

359

Kilovolts Sq. Root of Mean Square	Distance. Inches	Cms.	Kilovolts Sq. Root of Mean Square	Distance. Inches	Cms.
5	0.225	0.57	140	13.95	35.4
10	0.47	1.19	150	15.0	38.1
15	0.725	1.84	160	16.05	40.7
20	1.0	2.54	170	17.10	43.4
25	1.3	3.3	180	18.15	46.1
30	1.625	4.1	190	19.20	48.8
35	2.0	5.1	200	20.25	51.4
40	2.45	6.2	210	21.30	54.1
45	2.95	7.5	220	22.35	56.8
50	3.55	9.0	230	23.40	59.4
60	4.65	11.8	240	24.45	62.1
70	5.85	14.9	250	25.50	64.7
80	7.1	18.0	260	26.50	67.3
90	8.35	21.2	270	27.50	69.8
100	9.6	24.4	280	28.50	72.4
110	10.75	27.3	290	29.50	74.9
120	11.85	30.1	300	30.50	77.4
130	12.90	32.8			

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APPENDIX E. TEMPERATURE COEFFICIENTS.

360 Table of Temperature Coefficients of Resistivity in Copper at Different Initial Temperatures Centigrade.

Initial temperature cent. i	Temp. coefficient. in percent. per degree cent.	Initial temperature cent. i	Temp. coefficient. in percent. per degree cent.
0	0.4200	26	0.3786
1	0.4182	27	0 3772
2	0 4165	28	0.3758
3	0.4148	29	0.3744
4	0.4131	30	0.3730
5	0.4114	31	0.3716
6	0.4097	32	0.3702
7	0 4080	33	0.3689
8	0.4063	34	0.3675
9	0.4047	35	0.3662
10	0.4031	36	0.3648
11	0.4015	37	0 3635
12	0.3999	38	0.3622
13	0.3983	39	0.3609
14	0.3967	40	0.3596
15	0.3951	41	0.3583
16	0.3936	42	0 3570
17	0.3920	43	0.3557
18	0.3905	44	0.3545
19	0.3890	45	0.3532
20	0.3875	46	0.3520
21	0.3860	47	0.3508
22	0.3845	48	0.3495
23	0.3830	49	0.4383
24	0.3815	50	0.3471
25	0.3801		

The fundamental relation between the increase of resistance in copper and the rise of temperature may be taken as

$$R_t = R_0 \ (1 + 0.0042\ t)$$

where R_0 is the resistance of the copper conductor at 0° C. and R_t is the corresponding resistance at t° C. This is equivalent to taking a temperature coefficient of 0.42% per deg. C. temperature rise above 0° C. For initial temperatures other than 0° C., a similar formula may be used substituting the coefficients in the above table corresponding to the actual initial temperature. The formula thus becomes at 25° C.

$$R_{i+r} = R_i \ (1 + \frac{0.3801\ r}{100})$$

where R_i is the initial resistance at 25° C. R_{i+r} the final resistance and r the temperature rise above 25° C.

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In order to find the temperature rise in degrees cent. from the initial resistance R_i at the initial temperature i^0 C. and the final resistance R_{i+r} we may use the formula

$$r = (238.1+i)\left(\frac{R_{i+r}}{R_i}-1\right) \text{ degrees C.}$$

See Sec. 265.

HISTORY OF THE STANDARDIZATION RULES A.I.E.E.

In Connection with the Presentation of the Standardization Rules to the American Institute Electrical Engineers at the 23d Annual Convention Held at Niagara Falls, June 27, 1907.

The first step taken by the Institute toward the standardization of electrical apparatus and methods was a topical discussion on "The Standardization of Generators, Motors and Transformers," which took place simultaneously in New York and Chicago on the evening of January 26, 1898. This discussion appears in the Institute Transactions, Vol. XV, pages 3 to 32. The opinions expressed were generally favorable to the scheme of standardization of electrical apparatus, although some members feared that difficulties might arise. As a result of this discussion, a Committee on Standardization was appointed by the Council of the Institute, consisting of the following members:

Francis B. Crocker, *Chairman*.

Cary T. Hutchinson, Charles P. Steinmetz
Arthur E. Kennelly, Lewis B. Stillwell
John W. Lieb, Jr., Elihu Thomson

After a careful consideration of the matter and consultation with the members of the Institute and interested parties generally, a "Report of the Committee on Standardization." was presented and accepted by the Institute, June 26, 1899. These original rules appeared in the Institute Transactions, Vol. XVI, pages 255 to 268.

As a result of changes and developments in the electric art, it was subsequently found necessary to revise the original report, this work being carried out by the following Committee on Standardization:

Francis B. Crocker, *Chairman*.

Arthur E. Kennelly, Charles P. Steinmetz
John W. Lieb, Jr., Lewis B. Stillwell
C. O. Mailloux, Elihu Thomson

This revised report was adopted at the 19th Annual Convention at Great Barrington, Mass., on June 20, 1902, and appears in the Institute Transactions, Vol. XIX, pages 1075 to 1092.

In consequence of still further change and development in electrical apparatus and methods, it was decided in September, 1905, that a second

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revision was needed, and the following Committee was appointed to do this work:

FRANCIS B. CROCKER, *Chairman.*
ARTHUR E. KENNELLY, *Secretary.*

HENRY S. CARHART	CHARLES F. SCOTT
JOHN W. LIEB, JR.	CHARLES P. STEINMETZ
C. O. MAILLOUX	HENRY G. STOTT
ROBERT B. OWENS	S. W. STRATTON

This Committee held monthly meetings and carried on extensive correspondence with manufacturers, consulting and operating engineers and other interested parties, and as a result, presented its report at the 23d Annual Convention, held at Milwaukee, May 28-30, 1906. After considerable discussion the report was accepted and referred back to the Committee for amendment and rearrangement in form. It was then to be submitted to the Board of Directors for final adoption. In September, 1906, the following Standardization Committee was appointed:

FRANCIS B. CROCKER, *Chairman.*
ARTHUR E. KENNELLY, *Secretary.*

A. W. BERRESFORD	CHARLES P. STEINMETZ
C. O. MAILLOUX	HENRY G. STOTT
R. B. OWENS	S. W. STRATTON
CHARLES F. SCOTT	ELIHU THOMSON

This Committee held monthly meetings, also sub-committee meetings, and carefully referred the rules as a whole, and each part of them, to the members of the Institute. The rules were also entirely rearranged as to form, and put in shape to facilitate ready reference to them and enable future revisions to be made without breaking up the logical arrangement. Thus amended the rules were submitted to the Board of Directors and approved by it on June 21, 1907. The Board also directed that the rules should be presented, as accepted by the Board, at the Annual Convention held at Niagara Falls, June 24 to 27, 1907, which action was taken by President Sheldon on June 26, 1905. By the Constitution which went into effect June 10, 1907, this Committee has been made a standing committee with the title "Standards Committee," consisting of nine members.

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A paper presented at the 24th Annual Convention of the American Institute of Electrical Engineers, Niagara Falls, N. Y., June 27, 1907.

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ON THE CONCENTRIC METHOD OF TEACHING ELECTRICAL ENGINEERING

BY V. KARAPETOFF

Introduction. The aims in teaching electrical engineering must be in accord with the demands of the electrical industry, and with the needs of the country, broadly understood. The details of electrotechnical pedagogics should properly be discussed among the teachers themselves, but the principles and the aims should be established through close coöperation with national technical bodies, such as the American Institute of Electrical Engineers.

The manufacturer of machinery learns from the user in how far his product has been successful; so the teachers of electrical engineering turn to the representatives of the electrical industry at large for advice and direction. The teacher of engineering wants to know what product is desired, and what faults are found in present technical graduates.

The concentric method of education outlined below is one which it is thought will supply the needs of industry better than the present method. *From theory to practice is the present motto; from practice to theory is the new principle proposed.*

Some Remarks on the Present Method

The established educational custom is to begin the teaching of every technical subject with *theory*, gradually turning to *practice*, as based on theory. That this method is the only logical one has seemed to be almost self-evident, it being generally understood that practice cannot be taught without theory. But the question is, can theory be successfully taught without

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previous practice? Is teaching engineering merely the filling of a man's mind with detached facts, or does it mean developing his ability, to the end that he may think logically in his profession, getting correct results by correct processes? If the latter, the coöperation of the student must be secured at the very start and maintained throughout the course. The immature mind of eighteen years is entirely blank so far as the theory and practice of engineering are concerned. Can this coöperation be secured more easily by teaching him abstract auxiliary sciences, like mathematics, mechanics, and physics, as is now done, or by hurrying him into his profession at the very outset?

The writer's principal objection to the present method of teaching engineering is that student is burdened with abstract *auxiliary* sciences during the first two years of his college course, before he has had even a taste of his profession. The conscious coöperation of the student is not assured. Rather, he follows the prescribed courses blindly on the supposition that he is being properly cared for. It always reminds me of going to a dentist or to a barber, where we pay a specialist and passively submit to an unpleasant but inevitable operation.

It is perfectly evident to us that mathematics and mechanics, physics and chemistry, constitute necessary correlatives for engineering courses, just as history and economics are necessary for the study of the law. But this is not obvious to the beginner; he is all at sea in studying subjects without knowing their application. *All auxiliary subjects of study must follow the principal study and not precede it, as is the case with the present system.* I know this would mean to reverse entirely all the present plans of instruction, but what is right ought to be done at any cost.

No subject should be taught in which an interest can not be aroused. This means, do not begin with the elements, because they are not interesting; "*begin from the end.*" In teaching Latin do not give in the freshman year dry grammar and other dead stuff. Begin by reading the best examples of Roman literature in English translations. Then let the boys decide whether it is worth while for them to spend several years in studying the language in order to enjoy these same monuments of human genius in their original form. Is not a great mistake committed continually in making our young people study dead languages for years, only to find in the end that ninety-nine per cent.

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of them cannot then read Latin and Greek authors well enough to enjoy them.

The same mistake is made in mechanic arts, by beginning the course with elementary operations, forging, filing, etc., which arouse very little interest. Let the freshman begin his work by making a simple but complete piece of apparatus, wherein all the essential operations enter in their simplest form; let him discover himself the necessity of all these operations, then begin to study them in detail. If a student cannot be interested in making a piece of machinery where he has to perform all shop operations, this student is not fitted for the engineering course, and should be advised to change his specialty. *But if he is interested, then his coöperation is assured* and it becomes an easy task to teach him the details of his profession.

A great problem before technical educators is the evil of early specialization. But teaching mathematics and physics is no remedy; a true broadening effect is exerted only by a study of actual life, of practical economic conditions. Explain to the freshman the significance that various branches of engineering possess for the welfare of the country; this will have a much more broadening effect than studying the equation of an ellipse or the properties of barium. This is exactly what the proposed concentric method has in view, as may be gathered by reference to the schedules in the appendix to this paper.

In colleges of applied science all courses of instruction should consist, in the freshman year, in explaining the practical side of the profession and the social standing and opportunities of men in them. The engineering colleges should demonstrate the operation and application of all kinds of machinery; the practical side of building bridges and constructing railroads, etc. The college of law should have popular lectures on the practical work of lawyers, judges, and other men engaged in preserving justice among men. The college of medicine should give practical demonstrations in different specialties of medical work, and so on. A freshman should be offered an opportunity to go to all these lectures and to see what specialty he likes best. Let him even lose (?) a year if he has not selected any profession; for this is much better than to study three years under the present system, and, after coming to his senior year, to the practical side of his profession, to find himself sadly mistaken in his expectations.

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Let us begin from the end, then, let us exchange the freshman and the senior years; let us first give the student the fruits of knowledge; then, if he likes them, he will be interested to learn of their theories and foundations. Of course, freshmen cannot be taught engineering or law in the same way that these subjects are taught to juniors and seniors; but who would venture to say that these subjects could not be taught in a more popular and interesting manner than at present?

What the Concentric Method Is

The method of instruction for which the author stands may properly be called the "concentric method," and is represented

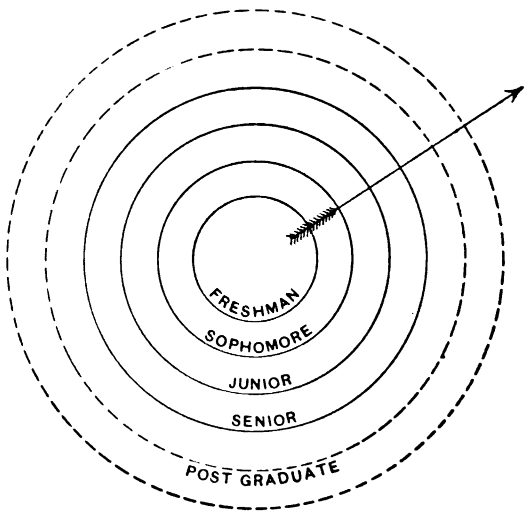

Fig. 1—Concentrically widening the student's mental horizon

graphically (Fig. 1) by a series of concentric circles; each zone comprises as far as possible the whole scope of a given specialty. The knowledge represented by different zones differs only in the degree of specialization.

During the freshman year (inner circle) the student is introduced to the whole scope of his profession, though in a very elementary, popular manner. The next year (second zone) he studies the same subjects from a somewhat more special point of view. The third zone represents the same subjects still more advanced, etc. For example, in applying this method to the study of history, the first zone would represent a broad

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sketch of the destinies of different nations; the next zone would be a more detailed treatment of the most important historical periods; the third zone might include a critical study of original sources and actual remains: and the fourth, the philosophy of history. Or, in studying the steam engine, the first circle corresponds to a purely descriptive sketch of the operation—handling and troubles—the second a more detailed study of the parts and an experimental investigation of the accompanying phenomena; the third year would comprise the theory of these phenomena from the standpoint of thermodynamics, mechanics, strength of materials, etc. The outer zone would represent design and special investigations. The dotted circles on the

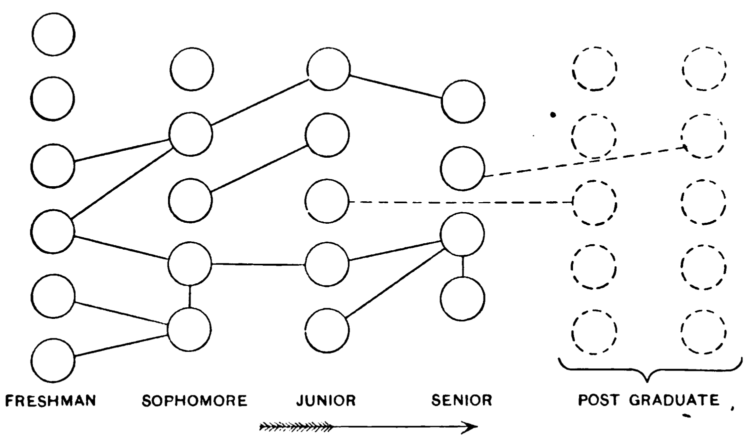

FIG. 2—Lack of system in the present way of instruction (subject method)

diagram represent advanced post-graduate work and symbolize infinity of knowledge.

In contradistinction to this system, the method now in vogue, or the "subject method," is represented in Fig. 2. Here the student begins his freshman year by studying several subjects of an abstract character, subjects having no relation whatever to each other. They are in part auxiliaries for consecutive studies, in part are supposed to develop logical thinking and imagination. The subjects introduced the second year are based partly on the studies of the previous year, partly represent new departure; but again their relation to the principal subject of study is not sufficiently evident to the student, so that he

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blindly and reluctantly follows the program, instead of coöperating actively.

In the third year, the professional studies begin, based on the sciences absorbed during the first two years. But these studies are again of too academic a character, too abstract, since the whole underlying idea with the present system is that practical applications must follow the general theory. Thus only in his senior year does the student come to the practical side of his profession. This method is probably the easiest for the teachers, because they also were educated in this way; but unfortunately it contradicts the very nature of man, and stands in contradiction to the educational aims of our times. The method has a distinct stamp of old scholastic culture based on the authority of precedent, rather than on free progressive thinking.

Some of the courses of study in the scheme shown in Fig. 2 are indicated separately from any consecutive courses, or are connected only to advanced problems (dotted connecting lines), which hardly one student out of a hundred takes; and still all students are required to take these preparatory courses in the freshman or sophomore year.

It is particularly sad that the student does not realize the necessity for many of the studies during his college years, and the significance of some of them remains an enigma through his entire life. What a difference between the natural development of a farmer boy and the artificial cramming of a student with knowledge, The boy learns the surrounding world in a purely "concentric" manner; the student is taught according to the "subject method." The farmer boy begins at once with botany, zoology, law, mechanic arts, and enlarges his knowledge gradually as he feels the need for it; and he is more and more interested in the results of such knowledge or experience. The student begins with the most abstract knowledge, or fragmentary practice, which he cannot connect with his life. The farmer boy lives to-day; constantly he applies his knowledge or at least realizes its use; the student lives with the expectation that some day he will understand the use of the dry stuff he is forced to imbibe, or perhaps be allowed to forget it. How can any great success be expected under such circumstances?

We are beginning to understand that true preparation for an activity consists not in mechanical ability to perform simple operations, or in knowing abstract elements. The mind of the

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man must be made receptive by impressing him with the important or interesting side of his subject; this can be done only by showing him the result before he begins an extensive study.

It seems that with our present system we are preparing students, not for ordinary commercial work which ninety-nine per cent. of them take up, but for special research work, which hardly one per cent. ever follow. In doing so we are involuntarily tempted to make of the students what we ourselves to some extent are—men pursuing more or less original research rather than regular commercial work. *Let us remember that we are supposed to prepare, not future professors, but men for industrial work, and that our first aim should be to comply with the needs of the industry.*

Our democratic and industrial times call for infinite stages of knowledge and ability. A man who thoroughly assimilates, say, two concentric circles of study is of more use to himself and to the nation than a man filled with useless undigested knowledge, though in his pocket he have a diploma from our greatest university.

Courses of Study According to the Concentric Method.

We will suppose now that the reader agrees with the above contention, that the best method of education is that in which the student gets first a bird's-eye view of his profession, and then improves and specializes in it. This method is in accord with our nature, permits everybody to go just as far as he can or wishes; an element of interest is introduced into the study; a hastily selected vocation may be easily changed, etc. The question arises: is this method practicable? Can courses of study be arranged according to the above principles? As an answer the writer gives below an outline of a complete four- or five-year course of study of electrical engineering according to the concentric method. It seems to him that any other subject could be arranged just as well, since electrical engineering is no exception.

The present course in mechanical and electrical engineering may be called "from abstract to concrete"; that is to say, the course begins with mathematics, mechanics, and physics, then passes through an intermediate stage of machine elements, strength of materials, drawing, etc., and finally advances to the electrical and mechanical engineering proper. The courses in engineering proper are also arranged somewhat from abstract

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to concrete, so that general theory precedes the experimental and empirical side of study. The proposed courses, arranged according to the concentric method, follow the opposite way, "from concrete to abstract", the idea of each year being characterized as follows:

Freshman. Introduction into electrical engineering (bird's-eye view).
Sophomore. Experimental electrical engineering.
Junior. Elementary theory of electrical engineering.
Senior. Advanced theory of electrical engineering.

Freshman year. The fundamental course of this year should be "Electricity in modern life," or "Cyclopedia of electrical engineering." This course should comprise the following divisions:

1. A popular outline of applying electricity to lighting, railways, telephones, signaling, metallurgy, chemistry, medicine, etc.; popular experiments must make it perfectly plain and intelligible to everyone, so that students of all departments could easily and with interest follow the course. This is in accordance with the idea that during the freshman year the student is not supposed to have definitely selected his specialty.
2. Talks on the general character of engineering work, on opportunities and social standing of engineers, on necessary qualifications for different kinds of work, etc.
3. A historical sketch of the development of the electrical industry, and its present state in this country and abroad.
4. Explanation of the concentric method pursued during the four years, and an outline of the consequent work during this course. This is desirable in order to insure the conscious cooperation of the student in his future work.

A similar course should be given in mechanical and possibly in civil engineering; these three courses constituting the most important part of the freshman year. If the student feels that he cannot yet decide to become an engineer, or what kind of engineer he wants to become, let him spend the rest of his time in going to similar popular lectures in other departments of the university. But if he has already decided that he is going to become an electrical engineer, he may be given some work in the shops and the laboratory. This should be not the so-called *elementary* work, consisting of filing, or measuring specific heat and resistances, but *practical* work, consisting of assembling

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and dismantling of apparatus, handling machinery, electric wiring and connections, etc., so that he may feel that he is already started in his profession. This consciousness would give him pride and satisfaction, and arouse his interest for further studies. *This purely psychological element of technical education is almost entirely lost sight of with the present system.*

Freshmen should not have more than, say, 12 hours a week of engineering work, and should be induced to take a few courses of a general character in other departments, rather than allowed to specialize in one kind of work. Experience may show that there will be some demand for mathematics and physics on the part of the students themselves; should such be the case, the corresponding courses could be easily provided.

The writer wishes to emphasize the fact that he by no means belongs to that class of "practical men" who sneer at any theory, and do not consider physics and mathematics as a part of engineering education. He himself is very fond of these sciences and preferably spends his hours of leisure in studying them. Yet he firmly believes that for engineering purposes physics and mathematics are of an auxiliary character and should be given the students only as such. Moreover, these sciences should be taught so that the student may clearly see their importance and necessity in his profession. Later on, during his senior year, or after graduation, a student who feels an academic interest in these sciences may specialize in them; but *his first duty during the freshman and sophomore years is to study engineering, and not physics and mathematics.*

Sophomore year. Electrical engineering should be treated during this year purely experimentally, keeping in mind that while the underlying phenomena are unchangeable, all our theories and explanations are rather poor excuses for our absolute ignorance of the true nature of electricity and magnetism. Thus the electrical engineering courses during this year should comprise construction and operation of electric machinery, lamps, street-car equipments, telegraph and telephone apparatus, etc., going more into detail than was possible during the freshman year, where it was necessary to establish in the first place the very possibility and scope of applications of electricity.

Hand in hand with this course should go electrical laboratory work, not in the sense usually applied now, that is to say for the purpose of getting some numerical results, but simply for the purpose of handling all kinds of electrical apparatus. This

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should impress the student that the apparatus studied is something real and substantial and not mere fiction or schemes drawn on the blackboard. Lectures in mechanical engineering and mechanical laboratory should be of about the same character; it is not at all necessary or important for an electrical engineer to know much about thermodynamic calculations, but he must be sure that, if necessary, he can take care of boilers, steam, and gas engines, pumps, etc.

Shop-work must again consist in making pieces of simple apparatus comprising as many different operations as possible; no "single" operations should be allowed at this stage, because it would immediately lower the interest in the work. As a novel feature, some electrical work might be introduced, such as making blade-switches, · simple measuring instruments, and spark-coils. In building such apparatus the student will meet with most of the shop operations and will get the necessary preparation for taking up regular shop theory and practice during the next year.

The study of mathematics, physics, and mechanics can be profitably begun during the sophomore year, provided they be taught *by an engineer and from the standpoint of engineering applications*, rather than abstract theory. Moreover, in order to link this course with engineering and with the mathematical knowledge required at the entrance examinations, this course should begin with applications of elementary mathematics to engineering problems, the students being tactfully brought to seemingly elementary problems, where analytics and the calculus become necessary. In this way the mind of the student is brought to an understanding of the practical importance of considering infinitesimal parts of time, length, volume, etc.; and thus partly by intuition, partly by application, he is introduced to analytics and the calculus.

Drawing, both freehand and mechanical, must be taught, not as an art by itself (unless the student desires it), but simply as a matter of necessity in shop work and in laboratory reports; the same holds true of descriptive geometry. The laboratory work, the shop practice, and possibly some class exercises should be so arranged that the students may *naturally* come to use drawings, both those given them and those made by themselves. Thus they will gradually recognize the necessity of plan, elevation, cross-section, perspective, schematic representation, and other technicalities. In the opinion of the writer,

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drawing should be taught in engineering colleges just as writing is taught in good primary schools. There the child is skillfully brought to an understanding of the advantages of putting down its needs on paper, and of reading the ideas of other people.

Junior year. Now comes the third year. With the present system the student begins dimly to realize at this time the very first principles of his specialty. With the system here proposed the student begins his third year with a more or less definite idea of the whole scope of his specialty; he knows that he is going to study the details of the work of the previous years and that he was lacking last year such auxiliary sciences as mathematics, physics, and chemistry. Now he is prepared to appreciate their significance; even more, he is already absolutely sure of their necessity, and is willing to accept the teacher's word even though he does not see its immediate application. Thus the work of the junior year should include a study of mathematics, physics, mechanics, chemistry (auxiliary sciences) with particular reference to electrical and mechanical engineering; at the same time a deeper insight into the specialty is made possible, assisted by these sciences.

The study of engineering may now be taken up with numerical relations. It is not necessary to go at once into higher mathematics, but merely to establish such relations as may be deduced from experiments, and which may immediately be applied to the solution of practical problems. With the training of the two previous years, the educator need not fear to go into details, since the student is already able to understand the significance and the place of a particular problem in the general field of electrical engineering.

To expect a student to investigate numerically this or that property of an electric machine the first time he sees the machine in the laboratory, as is the case under the present system, does not seem very rational. The purely qualitative and constructive side is of much more importance than any precise measurements. But if he has already had electric machines before him for two years, as with the proposed concentric method, he certainly can be made interested in numerical relations during the third year; and these measurements will be of a much better quality because he already knows how to handle machinery, apparatus, and measuring instruments.

Shop-work at this stage should consist in a systematic study of

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different operations: machining, forging, making castings, wood-work, etc. The work of the two previous years has shown the student *the necessity* of all these operations, and the relative positions they occupy in the processes of manufacturing. Now he will find interest in going into the details of each operation. Of course, it should be understood that the final purpose is to know how to direct and specify shop-work, rather than merely to acquire manual skill. This work should be supplemented by lectures on the subject, which would unify the methods taught in the shops, extend them beyond the possibilities of college shops, and also treat of cost of production and of methods of accounting.

Senior year. With the present system a senior hears for the first time the most elementary things in practical engineering; at the same time he knows (or is supposed to know) all about many theoretical laws and abstract relations studied during his junior and sophomore years. With the proposed concentric system he would already know a good deal about construction and operation of machinery from his three previous college years, but would lack the theoretical knowledge necessary for independent original work and design. The senior year is supposed to give him this, on the basis of the practical knowledge acquired during the previous years. Let us begin from the end.

The senior year should be devoted mostly to the theory of electrical and magnetic phenomena on the firm basis of previously established experimental relations. The educator may now boldly go into the very depths of mathematical analyses, for a senior understands their significance, whereas our present freshmen and sophomores merely get a chronic mental indigestion from the sight of mathematical formulas—an indigestion that often lasts a lifetime. It is a truism that the average technical graduate instinctively dodges differential coefficients and the symbol of integration.

In addition to pure theory, special elective courses should be given, such as electrical design, electric railways, telephony, etc. Such electives are given with the present system, but they are more of an elementary character, because the student is introduced into his profession too late.

For those theoretically inclined, an opportunity should be offered for studying mathematics, physics, and chemistry beyond the scope necessary for ordinary engineering practice.

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The Concentric and the Present Methods Diagrammatically Compared

The following two diagrams show the difference between the present schedules of instruction and the schedules arranged according to the concentric method. Lighter portions signify the practical side of the subjects, the darker portions refer to the theoretical side.

With the concentric method (Fig. 3) the student begins with the practical side of electrical engineering and with an elementary description of other branches of engineering activity. A considerable portion of time is allotted to general subjects, but

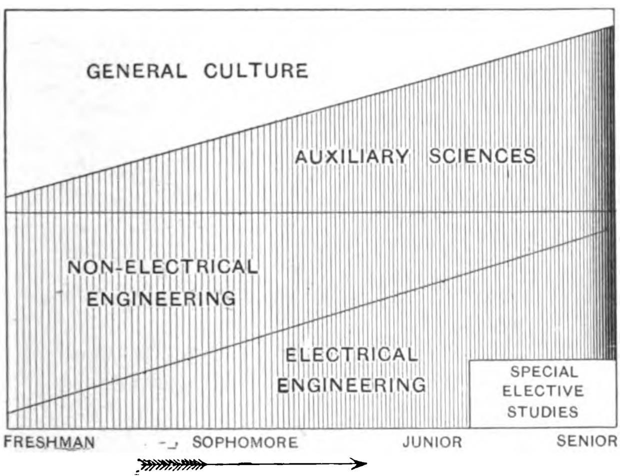

Fig. 3—Arrangement of subjects of study with the concentric method (from practice to theory)

practically no time to auxiliary sciences, such as mathematics, mechanics, and physics. As the course progresses, more and more time is devoted to electrical engineering, and less time to other branches of engineering and general culture. The studies themselves gradually become more rigid and theoretical. This naturally requires more and more time to be devoted to the auxiliary sciences. The small light portion in the senior year refers to practical elective studies (specialization).

In contradistinction to this scheme, the method now generally adopted is represented in Fig. 4. Here the first two years are practically filled with dry auxiliary studies, and the student does

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not get even a glimpse of his future profession until his junior year. And when he gets to his profession, the studies have again a theoretical character and only gradually become more and more practical.

A comparison of the two diagrams will clearly indicate the points of difference, and they do not require any further explanation. Those particularly interested in the subject will find these principles incorporated in the schedules printed below.

Conclusion

1. The study of engineering should begin in the freshman year and be carried throughout four years.

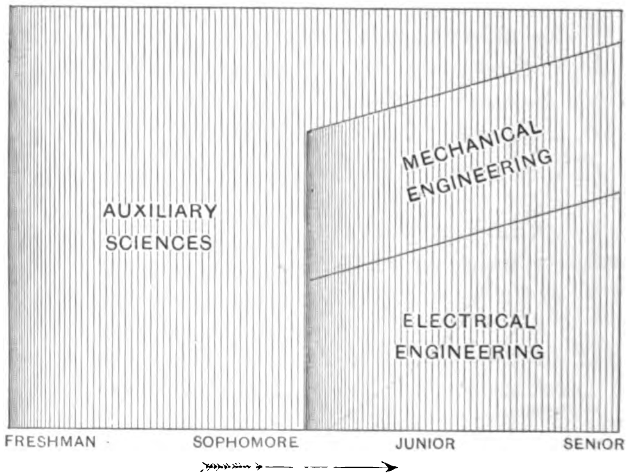

Fig. 4—Arrangement of subjects of study with the present method (from theory to practice)

2. Engineering instruction should be taken up with first giving a bird's-eye view of actual practice, and not with theory.

3. Auxiliary sciences, such as mathematics, mechanics, physics, and chemistry, should not be required further than is necessary for the understanding of engineering, and should be given later in the course.

4. Each year of study should be as much as possible self-contained, the mental horizon of the student being gradually and *concentrically* widened (Fig. 1).

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APPENDIX

Proposed schedules of study according to the Concentric Method. The numbers signify the number of hours per week for first and second term.

Freshman Year

(Suitable for all engineering students)

	Hours	
Cyclopedia of electrical engineering		2
" " mechanical "	2	
" " civil "	2	
" " mining "		2
Handling machinery	2	2
Making simple apparatus	2	2
Physical culture—one hour every day		
Electives.		
Law, medicine, history, economics, philosophy, languages, painting, music, etc	6	6
Recitations in at least three subjects	3	3
Total hours	17	17

Sophomore Year

(For mechanical engineers and electrical engineers)

	Hours	
Descriptive course in electrical engineering		3
" " steam "	3	
Principles of manufacturing		3
Mechanical laboratory	2	2
Electrical laboratory	2	2
Shop	2	2
Mathematics of engineering	3	3
Drawing in connection with laboratory and shop	2	2
Electives (non-engineering)	3	
Physical culture—one hour every day.		
Total hours	17	17

Junior Year

(Electrical engineers only)

	Hours	
Electric lighting	2	
Generators and motors		2
Electrical transmission		2
Electrical measurements	2	
Electrical shop-work		2
Electrical laboratory	2	2
Power engineering		4
Machine design	4	
Mechanical laboratory	2	

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Mathematics	4	
Mechanics		3
Physics		3
Chemistry	2	
Total hours	18	18

Senior year

(Electrical engineers only)

	Hours	
Electric and magnetic circuits	3	
Alternating currents		3
Theory of electrical machinery	2	2
Laboratory	3	3
Electrical calculations	2	2
Theoretical electives: Mathematics, Physics, Mechanics, Chemistry — two subjects to be taken		8
Practical electives: Electric railways, Telephony, Design, Power plants, Hydraulics, etc. — three subjects to be taken	8	
Total hours	18	18

A paper presented at the 24th Annual Convention of the American Institute of Electrical Engineers, Niagara Falls, N. Y., June 25, 1907.

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(Subject to final revision for the Transactions.)

DEFLOCCULATED GRAPHITE

BY EDWARD G. ACHESON

The subject-matter of this address is not in any sense electrical in character, but the effect described was discovered as the result of electrical work and the products obtainable by it may, with advantage, be used in electrical work and machinery. Such is my excuse for offering these remarks before this Institute.

In the year 1901, I was engaged in a series of experiments having as their object the production of crucibles from artificial graphite. In this work I was led into a study of clays. What I learned may be briefly stated as follows: 1. The American manufacturers of graphite crucibles imported from Germany the clay used by them as a binder of the graphite entering into the crucibles. 2. The Germany clays are much more plastic and have a greater tensile strength than American clays of similar chemical composition. 3. Residual clays—those found at or near the point at which the parent feldspathic rock was decomposed—are not in any sense as plastic or strong as the same clays are when found as sedimentary clays at a distance from their place of origin. 4. Chemical analysis failed to account for these decided differences.

I reasoned that the greater plasticity and tensile strength were developed during the period of transportation from the place of their formation to their final bed, and I thought it might be due to the presence of extracts from vegetation being in the waters which carried them. I made several experiments on clay with vegetable extracts, tannin being one of them, and I found that a moderately plastic, weak clay, when treated with a dilute solution of gallotannic acid or extract of straw, was increased in plasticity—made stronger in some cases as much

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as three hundred per cent.—required but 60 per cent. as much water to produce a given degree of fluidity, was caused to remain suspended in water, and made so fine in particles that it would pass through a fine filter-paper. Being acquainted with the record of how the Egyptians had the children of Israel use straw in the making of bricks, and believing it was used not for any benefits derivable from the weak fibres but for the extract, I called clay so treated Egyptianized clay.

Having in 1906 discovered a process of producing a fine pure unctuous graphite, I undertook to work out the details of its application as a lubricant. In the dry form, or mixed with grease or oil, it was easy to handle, but I wished it to enter the entire field of lubrication as occupied by oil. In my first efforts to suspend it in oil I met the same troubles encountered by my predecessors in this line of work; it would quickly settle out of the oil. My unctuous graphite was just plain simple graphite, and obeyed the same laws covering the natural product. So things stood until the latter part of 1906 when the thought occurred to me that tannin might have the same effect on graphite that it had on clay. I tried it with satisfactory results. I will now show you the effect and how it is produced.

I will take for the experiment two equal quantities of my unctuous graphite, as produced in the electrical furnace. When in this form, I call it disintegrated unctuous graphite. To one sample I will add plain water, and, after rubbing up in a mortar, I pour it into a test tube. To the other sample I will add water, a little gallotannic acid, and a few drops of ammonia. This last is not always necessary, but I find it improves the results with some waters. I will now rub the mixture in the mortar as in the first case, and then pour into a test tube. I will now shake up both tubes simultaneously and place them in a rack to settle.

Two minutes have now elapsed since the shaking and we find the graphite in the plain water has very completely separated from the water, not being miscible therewith, while the mixture of graphite, water, tannin, and ammonia remains as black as when shaken up. The graphite is miscible with the water in this mixture; it is suspended and would continue so indefinitely, at least I have found it to remain so for months, and I do not see why it should settle or separate the next day, week, month, or year.

While this experiment, as you have seen it performed, shows the effect, the result is much improved by time. I have here a

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bottle in which there are graphite, water, tannin, and ammonia which have been mixed for some weeks. The graphite is in what I call a deflocculated condition, a condition of fineness beyond that attainable by mechanical means, a condition approaching, if indeed not actually attaining, the molecular state. It is so fine as to pass with ease through the finest filter-paper. Here I have a glass funnel containing one of the finest filter-papers manufactured, and on this paper I will pour a little of the water and deflocculated graphite. See it run through the paper and collect in the tube, as black as ever and apparently unchanged. In fact it remains so black and has passed through so rapidly that a doubt exists in your minds as to its really being a mixture of water and solid matter—water and graphite. I can quickly convince you that such is the case.

Into the test tube containing the black liquid which has passed through the filter, I will now introduce a few drops of hydrochloric acid, and then slightly warm it over this spirit-lamp flame. These acts have caused the suspended graphite to floccluate and when I now pour the liquid onto a second filter paper, you see the water run through clear, the graphite remaining on the paper. Removing a little of the graphite and smearing it on a piece of paper, drying the paper and rubbing the black spot, it is at once recognized as graphite. This effect is obtainable with amorphous bodies generally; I have obtained it with alumina, lampblack, clay, graphite, and siloxicon.

I have successfully used deflocculated graphite in water instead of oil in sight drop-feed oilers and with chain-feed oilers. I have a shaft in my laboratory measuring $2\frac{5}{16}$ in. in diameter, revolving at 3000 revolutions per minute in a bearing 10 in. long that had no oil on it for a month, deflocculated graphite being the only lubricant used, the feed being by chain, and it ran perfectly. On the same shaft is a similar bearing lubricated with oil; this runs much the warmer of the two.

A few days after this test was started a pessimistic friend remarked that just plain simple water would give the same results, that the presence of graphite was unnecessary. We are influenced by the opinions of others even when we know or think they are wrong, so I emptied the oil out of the second bearing on the shaft and substituted plain water. The results during the first twelve hours seemed to support the contention of the friend. The next day after the machine had stood motionless over night things did not look so rosy for the water; it was a lame second on

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account of rust and was hurriedly removed. I think I shall not recommend clear water as a permanent lubricant.

Deflocculated graphite in water possesses the remarkable power of preventing rust or corrosion of iron or steel. This graphite, even after flocculation, is so fine in its particles that when dried *en masse* it forms a hard article. I have here a cake of dried deflocculated graphite. You can see it has the curvature of the watch glass in which it was dried. No pressure was used on it, but still you see it is comparatively hard, like a sun-dried clod of clay. It is self-bonding.

While, as I have stated, deflocculated graphite in water is an efficient lubricant, it has the drawback or disadvantage of losing its water by evaporation. I also appreciated that much time would be consumed in converting the world to water lubrication from the present one of oil. Therefore I set before me the problem of replacing the water medium with oil. A very great deal of difficulty and many discouraging conditions were met with, but I am pleased to say success was arrived at, and I have here a bottle containing kerosene oil holding about one-half per cent. of deflocculated graphite, that percentage being sufficient for most work. Here is another bottle containing spindle oil with a like percentage of graphite. The graphite has been in these oils for some weeks and shows no tendency to separate or to settle.

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A paper presented at the 219th Meeting of the American Institute of Electrical Engineers, New York May 21, 1907.

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(*Subject to final revision for the Transactions.*)

SOME FACTS AND PROBLEMS BEARING ON ELECTRIC TRUNK-LINE OPERATION.

BY FRANK J. SPRAGUE.

Certain memorable opinions, recently uttered by railroad men whose creative and administrative work, and wide experience entitle them to preeminence, command attention. In March last, the New York *Times* contained an interview with Mr. E. H. Harriman, who discussed at length various features of the present steam railroad situation; the influence of national and state legislation; the developments, needs, and present difficulties of operation; and the vital necessity of increase of capacity, measured in its broadest terms. Expressing his individual opinion that perhaps it might be better, considered from the standpoint of the steam locomotive, if a wider gauge than the present standard had originally been adopted, he went on to say:

> But perhaps it is chimerical to think now of rebuilding the railroads of the entire country, and of replacing the entire railroad equipment. If so, what is the best thing? Obviously, electricity. And I believe that the railroads will have to come to that, not only to get a larger unit of motor power and of distributing it over the train load, but on account of fuel. That brings up another phase of the existing conditions. We have to use up fuel to carry our fuel, and there are certain limitations here just as much as there are in car capacity or motive power, particularly when you consider the distribution of the coal producing regions with respect to the major avenues of traffic. The great saving resulting from the use of electricity is apparent, quite aside from the matter of increasing the tractive power and the train load. * * * * * * *
> The only relief which can be obtained through economies of physical operation must come through the outlay of enormous amounts of money such as would be involved in a general electrification or a change in gauge.

At the April meeting of the Buffalo Chamber of Commerce, Mr. W. C. Brown, senior vice-president of the New York Cen-

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tral Lines, likewise comprehensively discussed the present railway situation, and the influence of legislation and management upon credit, pointing out the "appalling blow to that credit," not so much because "of what has been done, as the manner and temper with which it has been done, and the fear of what may follow." The pressure upon the railroads, the imperative and continuing need of development and improvements, and the limitations in available capital—all were specially emphasized by this statement:

If the development and expansion of the nation is to go on, if the progress made during the last ten years may be accepted as in any respect

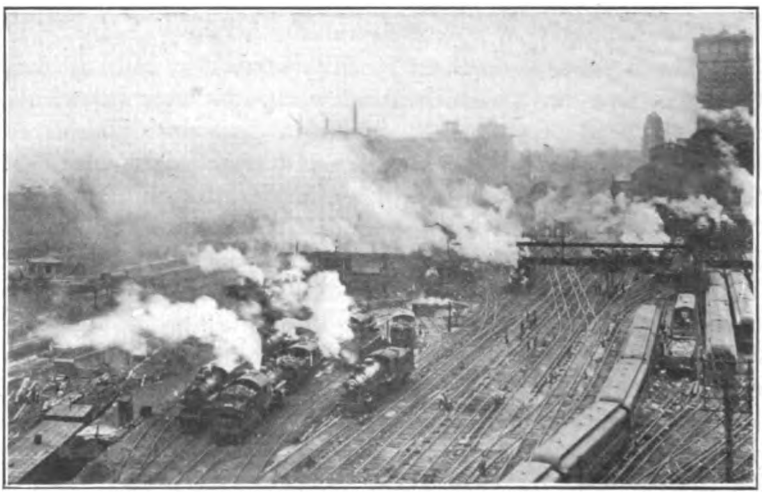

FIG. 1—Section of present steam terminal, New York Central.

a measure of progress to be made during the coming decade, almost as much money will have to be expended in increasing the facilities of existing railroads, and in building additional railroads, as has been expended during the eighty years since the beginning of the construction of railroads in the United States.

These opinions are confirmatory of that of Mr. James J. Hill, who some time ago startled the investing world by his estimate of a billion dollar annual expenditure, now actually confirmed by detailed estimates.

Coming from such high sources, from men who are fitted by nature and experience to survey the whole field with special clarity of vision, and to summarize their conclusions with

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extraordinary judgment, these utterances are pregnant with meaning; for coupled with the remainder of their remarks, they tell us that if there is the proper coöperation between the national and state governments and the railroad corporations, a permanently established confidence between the public and those who serve it, based upon integrity of management and equity of treatment, and a reasonably surety of a fair return on money invested—all absolutely necessary to command the confidence of capital—then in spite of temporary setbacks or trade reactions, this country has entered on an era of unequalled expansion, and when planning for future developments the steam railroads must keep in view the possibility of a change in motive power, and the adoption to an increasing extent of the use of electricity is some form.

But it is especially to be noted that while fuel economy, not only in the matter of power generation but also as affected by its own transportation (often a most serious matter) must be kept in view, the keynote of the prophecies of the future is more specifically sounded in the word *capacity*. It is this fact which must be always borne in mind.

Increase of capacity, not only such as is possible and individual to electric application, but also such as is common to the larger developments of railroads however operated, means of course economy in its highest sense, that is, saving in passenger and ton-mile operation, assuming that traffic increases at least in proportion to capital account, because of increased loads, reduced train crews, higher operating schedules, better distributed service, less dead time on sidings, less interruptions to schedule and greater freedom from accidents.

I believe that this question of capacity will be a far greater controlling factor in the electrification of trunk-lines than that of economy as narrowly measured by the cost of electrical horse power. I do not know of a single instance in which electricity has been adopted in which this feature has not been paramount, nor do I know of a road operated to-day which would sacrifice capacity to economy.

How much has been actually spent in steam railroad development, to which I assume Mr. Brown's reference is confined, it is impossible to tell, but that it is a stupendous amount, giving some suggestion of future capital demands, is evidenced by the fact that the total of the outstanding stock, bonds, and other obligations of the steam railroads in the United States now

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aggregates about $13,800,000,000; while similar obligations of the electric railroads, which began their commercial expansion with the signing of the Richmond contract almost twenty years ago to-day, exceed $3,500,000,000.

These are indeed stupendous totals, and when confronted with the possibilities of the future we may well be hopeful, while we ask: Along what lines will this great development naturally proceed? What improvements must necessarily take precedence? How shall the continuing expenditure of capital be conducted so as to safeguard a dividend on it?

We electrical engineers are ambitious, fairly courageous, and given to prophecy. We have much warrant for it, and every reason to be proud of what has been accomplished in an unmatched industrial progress; but we are a little apt to be prejudiced in favor of our own work, and perhaps somewhat partisan in promoting it. I think we often lack in large measure the familiar knowledge of railroad finance and operation that is necessary in dealing with the larger railroad problems, in order to insure our fairly weighing the importance and value of all the elements which must be considered.

Such, at least, is apparently the opinion of the friendly, but yet mildly sarcastic and somewhat pessimistic editor of the *Railroad Gazette*, who, referring to the recent meeting of the Institute of Electrical Engineers on the occasion of the presentation by Messrs. Stillwell and Putnam of their paper on the substitution of the electric motor for the steam locomotive, remarks:

> The pity about the meeting referred to is that there was no speaker there who knew as much about the practical requirements of railroading as he and the others did about the advantages and economies of electric propulsion.

This is quite likely true, for most people know a little more about their specialty than about the details of every business collaterally connected with it. But, really, the electrical engineers of the country, many of them professional civil and mechanical engineers as well, are not entirely destitute of a knowledge of both steam and electric operating conditions, nor can they all fairly be classed as a lot of unthinking enthusiasts; their knowledge and experience amount in the aggregate to a very respectable total.

But we must not take our genial critic too seriously, nor be over-much discouraged by his limitations of vision, for his is

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not the only publication that has trailed after accomplished facts in the electrical world, nor his the only voice that has been raised in doubtful protest on the eve of great developments. Heed, however, must be taken of the fact that trunk-line operation is in many respects a very different thing from that of urban or interurban railways and the attempt to introduce electricity into steam railroad operation must observe in the fullest measure these differences. We can, therefore, take the criticisms made of us in good nature, and I think win the proper support of steam railroad men, and come nearer to

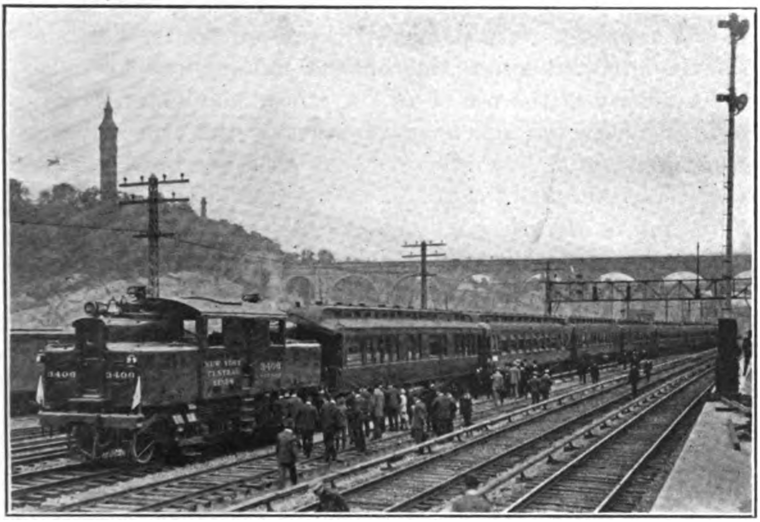

FIG. 2—First New York Central electric train, September 30, 1906. Leaving High Bridge for Grand Central Station.

the successful introduction of electricity where justified, by setting forth with entire frankness the facts as they have been, are, and promise to be, and avoiding too strenuous and arbitrary prophecies of what must be. You will note that I do not except myself from this generalization, and therefore I trust my engineer confrères will not deem me lacking in impartiality in formulating this gentle criticism.

Many of my hearers are young in years, and some of them just starting in railroad experience. Many statements made to-day may therefore have an air of novelty, but there are certain fundamental truths referring to the electric equipment of

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steam-operated trunk lines which have always, since the beginning of this development, been broadly true. I have stated them time and again during the last twenty years, and in a score of publications. I cannot state them any more fully now, but inasmuch as they are expressive of my present as well as past beliefs, and having been made at various times may now in part be lost sight of, I take the liberty of referring to them in an appendix to this paper, and I will briefly summarize a few extracts.

Fifteen years ago, in Chicago, I had the honor, as president of this Institute, to make my inaugural address on the subject: "Coming Developments of Electric Railways." On that occation, I may remark in passing, I expressed my fervent hope for a "single circuit alternating current motor," my conviction of the necessity of the use of an "overhead conductor, practically rigid in character, following very nearly the center line of all tracks and switches, with no movable overhead parts, and with return through the rail," and especially my belief in higher potentials and gearless motors.

My attitude on the broad question of trunk-line operation was then the same as it has consistently been since, for it has not been altered by more intimate contact with the trunk-line development. It may be briefly summarized in the simple statement that, taken as a whole the electrical equipment and operation of trunk lines is essentially more of a financial than a technical problem. It is certainly not solvable by ingenious methods of bookkeeping, or transmission of burdens to posterity. In that address I said:

> Any predictions which are made concerning the future of electric propulsion either in ignorance or disregard of the possibilities of steam duty, and the limitations necessarily existing in all systems of transportation, deserve and will receive little consideration from those charged with the responsibilities of conducting our great railway system, for unless passengers and goods can be moved over a system with increased benefit to a community, or at a reduced cost, or with a commensurate return on capital invested, an electric will not replace a steam system.

The commercial success of electric operation is a question of relative and absolute density of train movement.

> It narrows itself down to the one question as to the number of trains operated between the two terminal points. Make that number of trains sufficiently large, and the electric motor is the best means of electric propulsion. Decrease this number, and steam is to be preferred.

In closing that address, after pointing out the difficulties

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surrounding trunk-line operation, and the electric developments which it seemed to me would take place, I added:

Temper your enthusiasm with prudence; limit your attempts to the solution of those problems which will prove of practical benefit. Do not chase rainbows, but seek lessened costs of operation for equivalent duty and increased return on invested capital.

All this is said in no spirit of discouragement, for I yield to no man in my confidence in the future of electric traction. No new field is so rich, none more pregnant with great possibilities.

Where do we find ourselves to-day? Has there been any essential change in the essential governing facts?

Two years ago, we celebrated, and very rightly, the "Triumph of Electric Traction,"—not the wholesale replacement of steam by electric operation, that would have been somewhat prema-

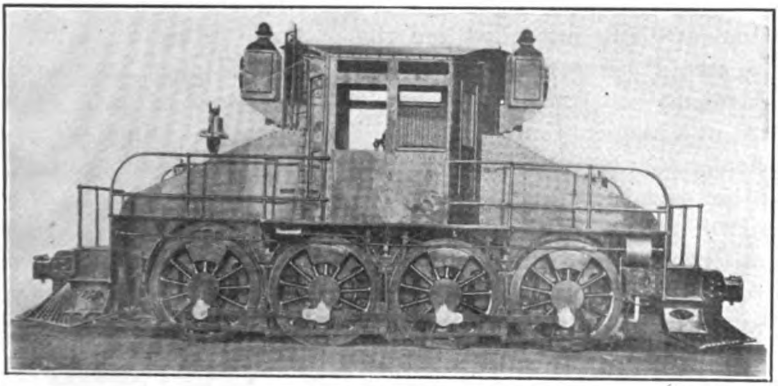

Fig. 3—Early Sprague, Duncan, and Hutchinson—1000 h. p. electric locomotive.

ture—but the magnificent results which had been achieved. A new industry had been created, affording investment for thousands of millions of capital, and employment for hundreds of thousands of men. Time, distance, and mountain elevations had been abbreviated, great vistas opened up, barren spaces peopled, new homes created, towns linked to each other and to their neighboring cities, and animal drudgery relieved. Direct-current, single-phase, and polyphase equipments were in operation; and a new system of power aggregation and control, the multiple unit, had solved elevated and underground problems, and made possible enormous concentration of capacity. The power and speed of the heaviest steam locomotives had been equalled or surpassed, and some of our great trunk lines had contracted

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for improvements costing over a hundred millions of dollars, made possible only because of the availability of electricity. But again referring to the broad question of trunk line operation, I felt impelled, even in that hour of elation, to say:

> What, then, will determine the future? Solely the financial factor, as it must the future of any other great industrial problem. When savings in operation and the increased returns from traffic on any road will more than pay a fair dividend on money invested for electrical equipment then, and then only will trunk lines, great or small, be operated electrically. As I have often stated, the problem resolves itself into a question of relative density and the character of load-factor, and these essentials are of course vitally connected with the allowed working potential.

Let us consider for a moment the evolution of the steam railroad. As a rule, it has started with a single track, with such contour and grades, weight of rail, and character of ballast as the money to be expended and the probable return in traffic have seemed to warrant, and generally handicapped by such extravagant or attempted profits in construction as have resulted in a long-continuing burden. Turn-outs and sidings were gradually supplemented by more sidings and longer turn-outs, and then such short sections of double tracking as the demands of capacity, traffic, schedule, and commercial conditions have required or permitted. Then there came a time, on many a road, of receivership, followed by reorganization and an extended period of recuperation; or if not receivership, then a long time of nursing into a condition of reasonable commercial health. As the demands of capacity increased, there followed the introduction of, or improvement in signal systems, additions to rolling stock, increases in the number and capacity of locomotives, until the road found itself with an equipment of extraordinary variety of varying conditions of efficiency; meanwhile, intermingled with a part of its own were all kinds of freight equipment from roads throughout the country. Through service for freight, express, passenger and sleeping cars, and terminal connections with other roads marked the transition from a road of more or less local to one of "through" character, The new relationship made an increasing demand on capacity. and double tracking became essential for a part, or perhaps for the whole of the route; and with this new demand likewise the necessity, oftentimes carried out beforehand, of some relocation of tracks, changes in alignment, reduction in grades, improvement in ballast, abolition of the more serious grade-

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crossings, especially near terminal cities, and extensions and improvements in, and enlargement of terminals and freight yards.

Now every one of these developments has been dictated primarily by one requirement—increase of capacity. This is the keynote of all railroad development, however rated, for it makes possible an increase of revenue miles of freight or passenger traffic which can be carried on a given trackage or operative mileage of road, and results in a net comparative economy of cost per ton of freight or passenger moved. These improvements are all vital, no matter what the motive power, and they should ordinarily and naturally precede the application of electric power, for it is absolutely certain, except in specific instances, that if these have not been made before the use of electricity is considered, they must be taken up in connection with its introduction.

Here, as during the whole period of growth, the financial question is always present, ever dominant. There probably never was an official charged with the maintenance and operation of a railroad who could not see opportunities for judicious expenditure of capital, and whose requirements have not generally been greater than would be acceded to by the directors and stockholders of his road. On the other hand, it is probably rarely the case that those same directors and stockholders have not wished that the demands made upon them for capital were less than the actual demands, even where granted. The practical question, then, which confronts every railroad is how best can such capital as can be raised on reasonable conditions—which conditions are always variable, and sometimes appallingly oppressive—be expended to meet the actual requirements of the road and to get the largest net return.

The enormous cost of railroad developments has necessarily in a large measure been first met out of the profits of operation, because of the difficulty of raising additional money on account of early extravagances in capitalization, expenditure, and management. Much of this cost often never appears in capital account, but in the end additions thereto must naturally and very properly be made to replace in some degree the amounts diverted from revenue.

In spite of many gross examples of railroad dishonesty, and many unfounded charges affecting railroad officials, it is but proper to repeat a statement made privately a short time ago by one of the best known of the higher railroad officials in this

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country, a man who has grown up from the ranks and is now in a position that commands the universal respect and esteem of all who know him, that, certainly within recent years, for every thousand dollars which has been added to capital account many thousands have been put into road and equipment from earnings that has never so appeared.

Electricity is no panacea for railroad ills, any more than freight and passenger rates arbitrarily determined without regard to cost of service is a panacea for the body politic. I know of no business in which universal averages as a guide for individual decision can be more unfortunately applied; and this is equally true, no matter what branch of the railroad business

FIG. 4—New York Central 2200 h.p. direct-current electric locomotive.

is considered. Statistics covering the operation of all the roads in the country may demonstrate to the mind of the mathematician that if all the power used were supplied electrically from central stations instead of by steam locomotives, there would be an enormous saving in cost of power, and therefore electricity should be adopted, no matter what the other demands for capital, or what the net result of an equal expenditure in other directions might accomplish. Such a comparison would, if anything, seem to mean that on those roads where traffic is congested, and where the demand of power per mile of road is not only large in the aggregate but on the average, considerations of power economy should be much more in-

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fluential; but they distinctly do not afford the slightest reason for assuming that the possible saving in power is of sufficient importance to lead to general consideration of electric operation on extended lines with sparse traffic, no matter what systems may be developed.

This criticism, if it may be so called, was objected to on the score that railroads of this latter class, while not properly present subjects for electrification, were changing their character, and that in time the density of traffic would be sufficient to warrant such adoption. This is precisely the point of my criticism. There are roads which can now properly consider the adoption of electricity. There are others which by no stretch of imagination can seriously consider it for many years to come, and the only time when they can do so will be when, by growth of traffic, development in the character of their equipment, and augumentation in financial strength they shall have arrived in the first rank of railroads. Why then dilute whatever advantages there are in the matter of economy—all of which are needed on even the best railroads—by consideration of such as are plainly out of present reach of electric equipment?

In discussing the subject of electrification of trunk lines, there is a tendency sometimes to ignore the varying conditions on the roads, and also the changes in methods of operation which the introduction of electricity may make possible. The railroads seem to be often regarded as systems which must be conducted very much on present lines, that is, operated with locomotive-drawn trains. In order to come to any clear decision, on many roads at least, this conception must be changed. There is no hard and fast rule of classification. A trunk line may generally be considered as a system joining important terminal cities, over which is conducted all kinds of traffic, through and local, passenger, express and freight, and, in the larger systems, a heavy suburban passenger service. The divisions and character of service of course vary widely, but the constant tendency is towards an increasing density of traffic, multiplication of tracks, and extension of the limits of local and suburban services.

When taking up the question of the adoption of electricity, railway officials are met at the outset by an unfortunate and confusing condition of affairs, largely due to manufacturing rivalries, individual partisanship, professional dicta, and gratuitous advice. These are in no small measure responsible for an apparent division of the engineering world into two

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camps, alternating and direct current, as in the earlier days of electric lighting, a division which it seems to me is entirely unnecessary and misleading.

At a recent meeting of the New York Railroad Club, the argument was advanced by one speaker that the general question of the adoption of electricity should be determined by a railroad quite independently of any details, and that systems, equipment, and methods of operation could then be safely determined. With this view I wish to dissent. A change of motive power involving vast expenditures of money and radical changes in methods of operation, cannot safely be determined upon except

FIG. 5—Group of eighteen 2200 h. p. electric locomotives.

after presentation of a comprehensive report, and a general plan of equipment and operation based upon an investigation of previous practice, present or pending developments, and an analysis of important features and details. And this seems all the more essential, for at the present time the technical press is filled, and the public ear vociferously afflicted, with the rival claims of the advocates of direct- and alternating-current systems; the merits and defects of single-phase, polyphase, and direct-current motors; and the beauties and ugliness, the danger and safety of various types of overhead and third-rail constructions. High and low potentials, 15- and 25-cycle frequencies, gearless and geared motors, and air and electric

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controls—all are actively exploited. Detail costs and economies, new methods of finance and bookkeeping, and changes in railroad operation and management are presented to the bewildered railroad man with enthusiastic confidence.

But above the discordant notes, and in the turmoil of varied developments there arises now and then the cry of standardization, not only such as is natural and not prohibitive of new advances in the art, but wholesale, explicit, and exclusive. For example, in a recent paper before this Institute, the view was expressed that but a single plan—the high-tension overhead trolley, with 15-cycle single-phase alternating-current motors—was possible of serious consideration on trunk line service, and that this system should now be adopted and standardized, despite the fact that there was not in existence a single equipment of this character in practical railway operation!

I do not intend to burden this paper with statistics, or abstruse mathematics—one can prove almost anything by them,—but just here I will epitomize certain conclusions which I think will bear the test of time.

1. Of the two broad lines on which electrification can be considered, if increased economy, that is, reduction of operative expenses by replacing the steam locomotive with an electric one, with concentration of prime power and perhaps the use of water power, be deemed the dominant reason for change of motive power, then every wheel in an electrified division should be turned electrically; and the savings affected should pay not only a fair rate of depreciation of the total equipment, but a satisfactory rate of interest on the new capital expended, in fact a better rate than if spent in some other way.

2. Increase of capacity, both in locomotive haulage, schedule speeds, motor-car trains and terminal facilities, of a character impossible to steam service—all resulting in augmented traffic, and increased use and capacity of the dead part of the systems, the tracks and roadbed—will ordinarily be the more potent influence in leading to the adoption of electric operation, and will often warrant heavy capital expenditures.

3. Every large road is a problem which must be considered financially and technically on its own merits, and in most features other than those which without effort can be harmonized its decision will be of little practical concern to other roads.

4. The adoption of electricity will ordinarily begin with those divisions where traffic is comparatively dense, and once

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adopted the territory over which it can be extended will naturally increase.

5. Terminal properties in great cities, underground and tunnel sections, and heavy mountain sections where duplication of tracks because of extra heavy construction cost is prohibitive offer an immediate field for the serious consideration of electrification.

6. There cannot now be safely established any final standard, or any single system selected as the best for all roads. What is the best for one might easily be less advantageous for another, and there is no valid reason why any road should adopt something fitting to a less degree its particular requirements because of the action of some foreign road.

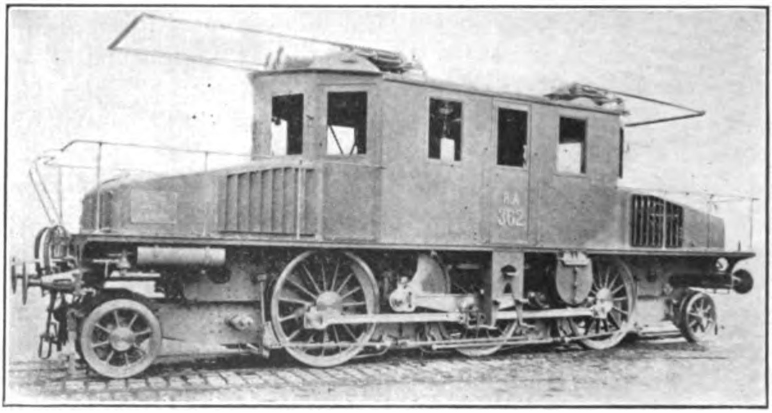

FIG. 6 -Ganz 1500 h.p. polyphase electric locomotive.

7. Extraordinary advances have been, and are being made, and new discoveries are always possible. The limits of none of the systems now in use are clearly defined, and it would seem both natural and wise that the various manufacturing, technical, and inventive activities should pursue every lead to its logical conclusion, for the best will be none too good.

It is not my intention in the present paper to investigate railroad economies, or to formulate any final conclusions in the matter of steam railway electrification, but rather briefly to analyze, and make running comment upon various phases of the problem often discussed by engineers; to give some comparative facts as they have thus far developed; to describe sundry developments in electric locomotive construction; and to illustrate in

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some detail features specifically characteristic of the three typical initial equipments now commanding attention.

Motor equipments. In discussing the selection of any system, the first thing to investigate is the motor. In railway operation that which is to be replaced is a steam locomotive, in other words, a motor supplied by a local boiler, furnace, and coal-bin: that which is proposed in its place is another motor, or group of motors supplied through a wire by bigger boilers, furnaces, and coal-bins, or by energy from a water power. The working conductor, with everything connected to it in transmission or generation, although essential, is tributary to the motor and its requirements.

It is not sufficient that the source of power can be made of any desired size, although it is an essential feature; in any case such concentrated generating equipment must supply a number of motors. What *is* essential, and in the last analysis vital, is that the new motor shall have not only certain mechanical advantages, to the extent of eliminating the evils of reciprocating parts and reducing the cost of up-keep, but above all it must have capacity, measured not alone by drawbar pull or speed, but by both, and it must be of sustained character; and this capacity, to accomplish more than the steam locomotive, must be greater than that of the latter. Such capacity should naturally be attained, first, by increase of the capacity of the individual motor or locomotive, and then, when this increase has reached its limit, by combining motors or locomotives under a common control by the multiple-unit system.

Limitation of design. The designing of electric railway apparatus is handicapped by certain physical limitations which it is not in the power of the designer to change; for example, gauge of track, size and number of drivers, length of rigid wheel-base, dead and total weights per wheel and axle, clearance of motors above the track, permissible speeds of parts, provision for accessibility and repairs, and capacity for heat radiation. Every steam locomotive, when properly designed, has capacity to slip its drivers on sanded tracks, and it can maintain nearly its maximum average drawbar pull for a considerable range of speed as long as its boilers can make sufficient steam. Although at the disadvantage of having reciprocating parts, its drivers being coupled together cannot slip individually. In short, it is designed of a weight necessary to get the tractive effort required to pull a definite load, and then for all the capacity in the matter of

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speed which its fire-box and boilers can provide for. Essential defects are that its drawbar pull varies widely, depending on the position of the connecting-rod, that it does not materially increase below a certain speed, and the steaming power is limited. Hence comes the limitation of the " ruling grade."

On the other hand, the electric locomotive, when likewise properly designed, provides a drawbar pull of constant character throughout the revolution of the driver, it increases to an extraordinary degree when necessary, and the capacity of the boiler supplied at the central station is ample. On all service, however high *continuous* capacity of the motor is essential.

Capacity being, therefore, the keynote of the equipment, I shall discuss at some 'ength the characteristics of conductors and motors used with direct current and with alternating current. In so far as these comments relate to single-phase alternating-current operation, they will in some measure be based upon the only existing commercial development of this character now in the United States, that is, upon the series-wound, commutating, single-phase motor with compensated fields, operated at 25 cycles.

Lowering the number of cycles to increase the capacity of the single-phase motor, as has been suggested although not yet developed in commercial practice, of course merits serious consideration, and I shall add some comments upon this proposed change.

Behavior of conductors. Both motors and conductors when used for direct current or for single-phase alternating current, present certain differences of such inherent character that there seems no present likelihood of material change; and this conclusion is as sound in regard to the motor-differences as it is in regard to conductors.

When used for single-phase alternating currents, conductors offer, by reason of self-induction, an impedance or resistance to current materially greater than they present to direct currents. This impedance, and the consequent loss of energy at any particular potential delivery, depends upon the shape and material of the conductor, upon the frequency of alternation, the density of current and the power-factor. Under ordinary conditions, a round copper conductor of, say, No. 0000 size has at 25 cycles an impedance of about 1.6. But with iron or steel conductors this impedance is increased many times, because the magnetization of the iron and the self-induction drive the current toward

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the skin of the conductor, so that the body of it is useless, and it might as well be a shell of very much less weight.

This effect in steel rails increases with the quality and with the cross-section of the rail. For example, according to the report of the test commission of the recent International Electrical Congress, on 50-lb. traffic rails the ratio of impedance to direct-current resistance at 25 cycles and 300 amperes is about 5.4, while on 80-lb., rail this ratio with the same current is 9.0, with the curious result that increasing the cross-section of the rail does not apparently increase its actual capacity for carrying single-phase currents. Quite the contrary, of course, is the fact in regard to direct currents, the conductivity increasing with the cross-section and quality.

These statements are made not because of special novelty, but in emphasizing certain inherent differences in conductors in their behavior toward the two kinds of current additional weight is lent to the statement that the differences inherent in direct-current and single-phase alternating-current motors are likewise radical, and are probably permanent in character.

Types of motor. Among the many types of motors proposed for railway service, four are now being exploited:

Polyphase	alternating-current	motor	
Single-phase	"	"	repulsion type
"	"	"	series type
Direct-current		"	

Of these, two, the direct-current and the three-phase motors, each have a continuous rate of energy-input, while the single-phase motor has an intermittent and variable rate. Moreover, there is combined in the single-phase motor two distinct functions, those of a motor and a transformer, and the latter cannot be entirely eliminated. The result is a reduction in both continuous and overload capacities.

It is in this particular that the single-phase motor, despite a great amount of experimental development, has remained defective; and while not prohibitive to the extent of making it an unworkable machine, its defects are so inherent as to place it at a serious disadvantage in individual comparison with other types of motors. To attain the preeminence hoped for, the external advantages in current supply must be very marked. In fact, rated in the same manner and under like physical conditions, it is only about half as good as the direct-current

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motor. Or to put it another way, the weight of the complete single-phase electrical equipment on a car or locomotive, including transformers, motors, and controlling apparatus, for continuous hard service, and with like physical limitations and ventilation, is about twice that required for direct-current apparatus. In addition to this there is, of course, a material increase in the mechanical equipment necessary to carry the electrical apparatus. The reason is simple—it is because of the heat generated on account of lower electrical efficiency, and the

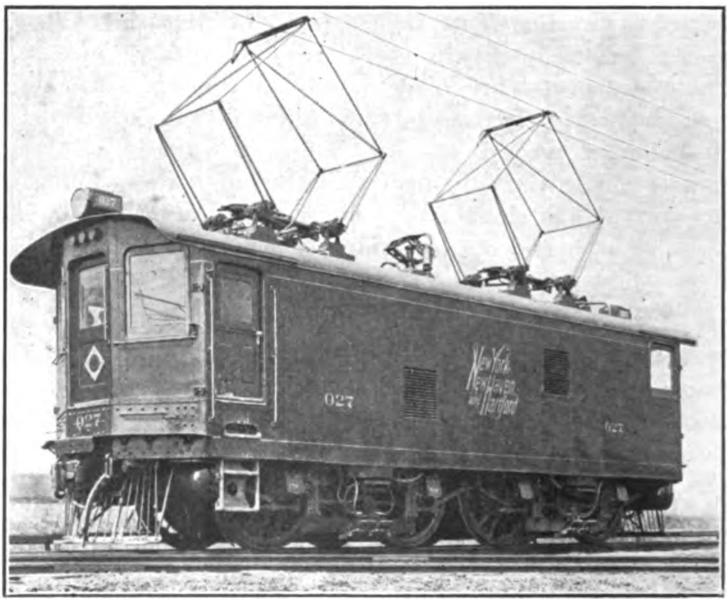

FIG. 7—New Haven 1000 h.p. alternating-current electric locomotive.

working the fields of the motors at a reduced magnetic flux.

When considering locomotives, the net result is that the total weight of a single-phase alternating-current locomotive, with a service capacity equal to that of a direct-current locomotive of like armature speeds and permissible temperature-rise (this temperature-rise being the ultimate limitation of a motor for continuous service) will easily be from 30 to 50 tons more.

An increase in the total weight of a train amounting to from 3% to 10% is perhaps not of itself of so much importance, be-

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cause such a difference in net power demand can easily appear for various reasons; but a ratio of 2 to 1 in capacity for the limit of equipment possible to install within given allowable dimensions and number of units is a matter of vital importance.

If an increased weight is permissible for any given capacity, there must be some ample compensation for it. Of course this is claimed to be the fact in the single-phase system, but another possible advantage which might prove important is the abolition of gearing and bearings, and simplification in motor and locomotive construction. Both advantages can hardly be hoped for.

Comparative weights of direct-current and 25-cycle single-phase alternating-current motors. While testimony is practically universal that not only is any single-phase motor, whatever the number of alternations, more or less inefficient than a direct-current motor of like weight or capacity, the differences of efficiency, excluding the losses in the gearing, are variously estimated.

A curious illusion relating to this subject seems to possess a number of well-known men, as was illustrated by an active discussion before the English Institution of Electrical Engineers of Mr. F. W. Carter's paper on, " Technical Consideration in Electric Railway Engineering," at the meeting in January, 1906. Mr. Mordey, while stating that there is a large difference in the efficiency of direct-current and single-phase alternating-current motors, claimed that inasmuch as we are concerned with the efficiency of the whole system it makes no difference where this loss appears, and that this difference of energy will easily appear in a direct-current system if the cars are not properly handled. Mr. Carter very properly corrected him, and pointed out that the location of this loss is vital, as it determines the heating of the motors, and if appearing in them it meant from two to three times the heat generated to be dissipated from the equipment. This is but another way of saying that a greatly increased weight of equipment is necessary with the machines of lower efficiency.

The reason for the reduced efficiency of the single-phase motor (whatever the actual amount, which depends upon a number of factors) is inherent, and is due to the transformer action which by increasing the losses limits the output of the motor. There is an additional loss of considerable consequence. Electrical efficiency, it must be borne in mind, is the ratio between the real output and input. The net input is, however,

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not the product of current and potential, as in a direct-current motor, but is affected by the phase-relation, commonly known as the power-factor; and when this is below 100% it means that the actual watts input is less than the product of potential and current or volt-amperes. To put it another way, the actual current input is greater than would be required if the power-factor were unity. As ordinarily rated, efficiency does not take account of this fact, but the increase of current actually means an increased I^2r loss, hence greater heating, and a consequent further reduction of motor-capacity.

It is well, just here, to point out that an increase of 10% in the amount of current used on a direct-current system, because of improper gear-ratio, change of schedule, or careless handling of equipments by motormen does not mean that this excess energy is dissipated in internal losses in the motors, for these may be increased only about one per cent. The situation in regard to the single-phase motor is, however, entirely different, for it is subject not only to increased power consumption with its proportionate losses because of careless operation, but it also has its individual increased internal loss, which is variously estimated to be much more than that found in properly designed direct-current motors of equal weight and like physical limitations.

Much, indeed, has been stated, and denied on this subject of the relative weights and capacities of direct-current and single-phase alternating-current equipments. On several occasions I have stated that, measured by equal physical limitations in speed and clearances, and for the same temperature-rise with natural ventilation, the total weight for any given service would be twice as much with the alternating-current apparatus as with the direct-current. A similar view has been expressed by other investigators, among whom I may mention Carter, Parshall, and Hobart.

Statements of this character, no matter how authoritatively and carefully made, seem to lie under the suspicion of individual prejudice. Since this is an engineering matter of so much importance, I have endeavored to get some exact facts. These will, I think, prove interesting, and I will show graphically, illustrating somewhat further by specific statements, the actual comparison between two motors of almost exactly the same weight.

It is customary to adopt a single-phase alternating-current

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motor rating which is based upon the performance of some direct-current motor. For example, a 125-h.p. single-phase machine is supposed to do the same work, that is, handle the total number of tons on some specified service, as a 125-h.p. direct-current motor. This may be an ingenious comparison, but it is a very specious and misleading. The fact is that such a motor equipment, including its transformer, will be very much heavier than the motor equipment with which it is compared, and consequently the net load which it can handle will be much less.

What *is* of vital consequence is a *comparison of capacities for equal weights*, not only of motors but of total apparatus which must be carried on a car, and also to compare the speed-relation and the polar-clearances, in other words, the allowable wear of bearings, all of which is quite aside from gear and commutator brush considerations, which are of themselves serious.

Valatin and others have indicated one measure of comparison between motors of different makes, types, and capacities—the "weight-coefficient,"—which for convenience may be expressed by the following equation:

$$\text{Weight-coefficient} = \frac{\text{Nominal rated horse power}}{\text{Revolutions} \times \text{weight in tons}}$$

This is a factor of the greatest importance, and it should be considered not only for the one-hour 75°-rise load, but throughout the whole thermal curve.

Let us investigate two motors, which for convenience we will call X and Y, both standard modern machines.

An initial comparison is as per this table.

Machine	*Type*	*Voltage*	*Air-gap*	*1-hr. rating*	*Weight*
X	d.c.	550	0.25	240 h.p.	5,474 lb.
Y	25∼a.c.	225	0.10	125 h.p.	5,327 lb.

The weights are minus pinions, gear, and gear-cases. There is a difference of less than 3% in net weights, or about 2.5% in total weights. They can, therefore, be very properly compared.

In passing, I would call attention to the air-gaps, that of the direct-current motor being nearly three times that of the alternat-current motor—a difference of vital importance as affecting allowable bearing-wear, and the proper functioning of the armature circuits under practical operating conditions.

The accompanying curves (Fig. 8) show graphically, almost

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startingly, the comparative speeds, capacities, and weight-coefficients of these machines, all referred to the time required to

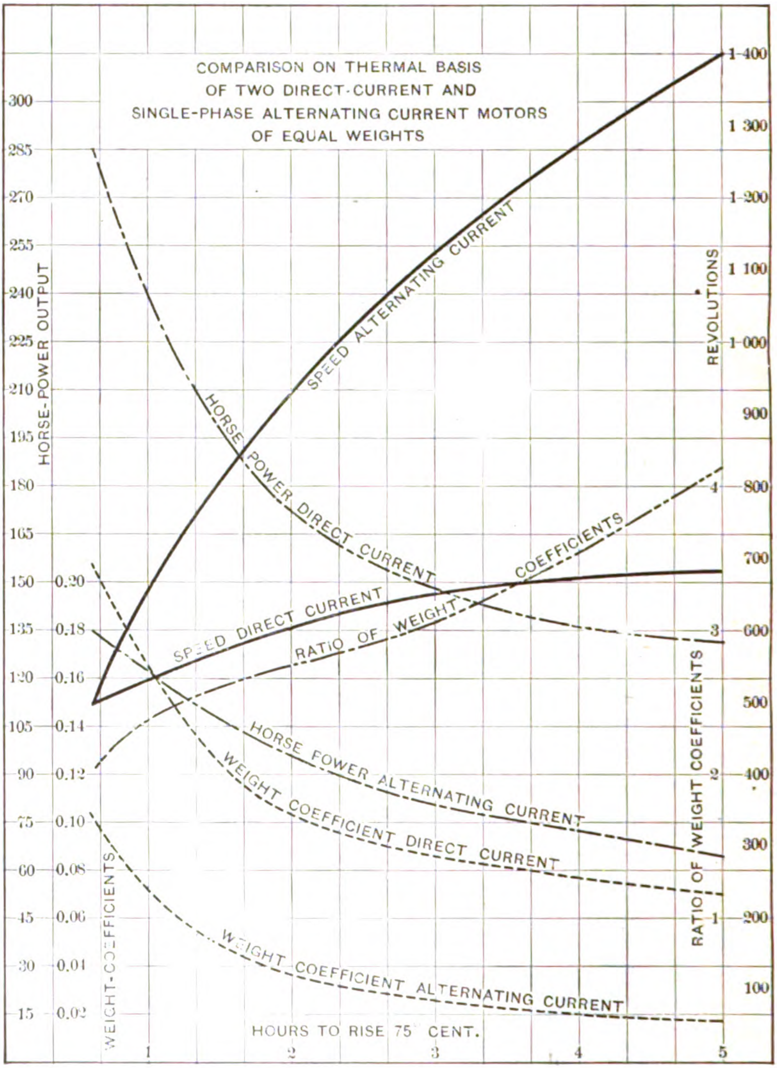

FIG. 8.

rise 75° in temperature when operating at full normal potential under varying loads and with natural ventilation.

It so happens that these two motors have the same speed—

500 revolutions—when run at their proper potentials for 39 minutes with such loads as will give temperature rises of 75°, and hence this will be taken as the starting point, and the characteristics noted for various runs up to five hours.

Inspection of these curves shows the following comparisons:

Time for 75° rise	Capacities D. C.	A. C.	Ratio of capacities D.C. ÷ A.C.	Speeds D. C.	A. C.	Ratio of speeds D.C. ÷ A.C.	Wt. Coefs. D.C	A.C.	Ratio of Wt. coefs. D. C. ÷ A. C.
39 min.	285	134	2.13	500	509	1.00	0 208	0.101	2.06
1 hr.	241	122	1.98	530	664	0.80	0.166	0.070	2.37
2 "	172	95	1.81	602	932	0 65	0.104	0.038	2.74
3 "	148	81	1.83	650	1130	0.57	0.083	0 027	3 07
4 "	137	72	1.90	670	1270	0.53	0.075	0.021	3.57
5 "	132	64	2.06	690	1398	0.50	0.070	0.017	4.12

Generally speaking, it will be noted that: starting at 500 revolutions for a 39-minute run, the capacity of the direct-current motor averages approximately nearly double that of the alternating-current throughout the thermal range; the speed of the alternating-current motor rises at a much more rapid rate, until on a five-hour run it is double that of the direct-current motor, despite the fact that it is only developing one half the power; the direct-current motor has a 5-hour capacity in excess of the 1-hour capacity of the alternating-current motor; and the ratio of the weight-coefficients, beginning at a trifle of over 2 to 1, rises to more than 4 to 1 in favor of the direct-current motor on the longer runs. This comparison of weight-coefficients does not include the collectors, control-switches, rheostats, transformers, or wiring, which in the aggregate are enough heavier for the alternating-current motor to maintain these disparities.

It is evident, therefore, that a pair of these alternating-current motors can handle only about one half of the total load of the direct-current motors, with all the disadvantage of higher armature speed and smaller air-gaps; and considering the excess weight of the control apparatus, the net load over and above the electric equipment would be considerably less than one half.

This general comparison is not, so far as the relative characteristics are concerned, individual to this particular size of motor, but seems to be equally applicable through a wide range, and indifferently as to the make, or whether the alternating-current motor is of the series-compensated or the repulsion type. Furthermore, these differences are seemingly so inherent that there is little chance for improvement at 25 cycles.

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Let us see the practical application of these facts. The passenger service on a certain typical trunk-line division requires cars of such size that, operated on a direct-current system they would be equipped with 2 X's, and if on a 25-cycle current system with 4 Y's. With equal seating capacity the following are actual comparisons:

a. Total weights of electric equipment, including 500 lb. excess on trucks:

Alternating current,	(4 Y's)	35,000 lb.
Direct current,	(2 X's)	16,000 "
Excess a.c. over d.c.	(118%)	19,000 lb.

b. Total nominal rating of equipments:

Alternating current,	(4 Y's)	500 h.p
Direct current,	(2 X's)	480 "

c. Rating per ton of total weight, including car-body and seated passengers:

Alternating current,	(4 Y's)	9.92 h.p
Direct current,	(2 X's)	10.67 "

d. Approximate costs of electric equipment:

Alternating current,	(4 Y's)
Direct current,	(2 X's)
Excess alternating current over direct current	(100%)

Polyphase and direct-current motor characteristics. Opposed to the two types of single-phase motors are the polyphase and the direct-current motors, the former with a rotating field, and the latter with a field of fixed character. They have similarly high weight-efficiencies, the former having somewhat the advantage when compared with the ordinary type of direct-current motor.

The polyphase motor, however, is a normally constant-speed machine. It can, through a re-arrangement of fields, be run at two different speeds; but each is practically a constant one. Or where there is a plurality of motors, half and full speed can be obtained by having one pair of different character from the other, and operated in cascade relation to it, with the necessity, however, of throwing one pair of motors out of service when running at full speed. With cascade operation and field changing combined there can be three running speeds. These motors, so far as their supply is concerned, have been limited for practical reasons to a potential of 3,000 volts on the trolley, because the

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supply requires, besides the rail, two wires overhead, although a recent undertaking in the United States, the operation in the Cascade Tunnel, is to be attempted at 6000 volts.

Polyphase motors have an enormous overload capacity, and the fact that they run at synchronous speeds with a very small slip, and if the frequency is unchanged will run upgrade nearly as fast as on a level, would indicate at first

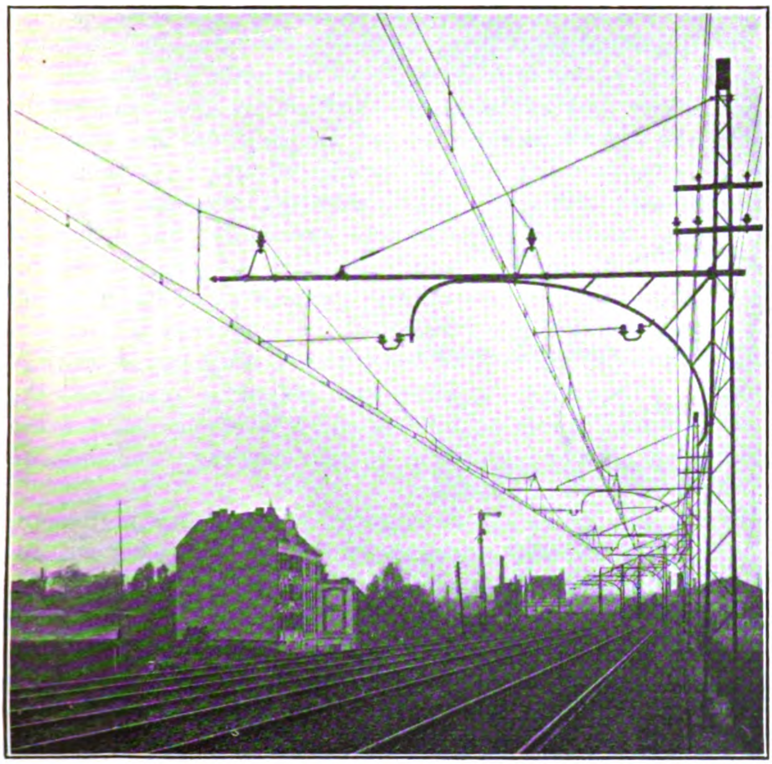

FIG. 9—Multiple catenary on Blankenese-Ohlsdorf Railway

sight excessive loads on main and sub-stations. But a curious and perfectly natural result has been pointed out by Cserhati and von Kando; namely, that with suitable provision for regulation at the central station, so that with excessive loads the generators will drop in speed, there will, with such speed reduction, be not only a temporary cessation of drawing power by the locomotive, but there may actually be a return of energy

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to the line while slowing down. While of course this slowing down affects all trains on a system, it is quite conceivable that when there are a number of trains in operation a mean result may easily be attained which will, in the matter of load-fluctuation, compare favorably with that of any other system. Multiple-unit grouping and operation is ordinarily impracticable because of the small slip. In spite of the splendid work done by the Ganz Company, and the strong support of many Italian engineers, I feel that, all things considered, neither the motor characteristics nor the limitations of overhead construction are acceptable for such service and conditions as exist on our trunk-line roads.

On the other hand, considered by itself, the direct-current motor, with its high average weight efficiency, simplicity of construction, facility of control, automatic response in torque and speed to varying grades and curvatures, and great sustained capacity for enormous torque at low speed, besides the advantages of speed-ranges obtained by motor-grouping, and the use of a single conductor and track return, offers a most effective machine to meet the conditions of railway service. Through it, as with the polyphase machine, the "ruling grade," often of limited length, is eliminated, for the motor can always respond to these temporary demands up to the limit of track-adhesion.

In the matter of speed-variation, the ordinary four-motor locomotive has, with proper control, three impressed electromotive forces, for each of which there is the same torque with a given current, while the aggregate current from the line varies as does the speed of the locomotive itself at any fixed torque, about 400 per cent. For each of the combinations there is a wide controlled automatic range of torque and speed, which as the sustained torque increases is far beyond the limits of the single-phase motor, and for a wide range of torque there is possible a considerable variation of speed by field-shunting.

These various features of torque- and speed-control are of the utmost importance when, under some abnormal conditions of traffic, it may become necessary to relieve the demand on the supply, although maintaining a high drawbar pull, or when, as in the operation of snow-plows a number of pushing locomotives under a single control must run at slow speed for considerable periods of time.

Direct-current motor improvements. During the last two

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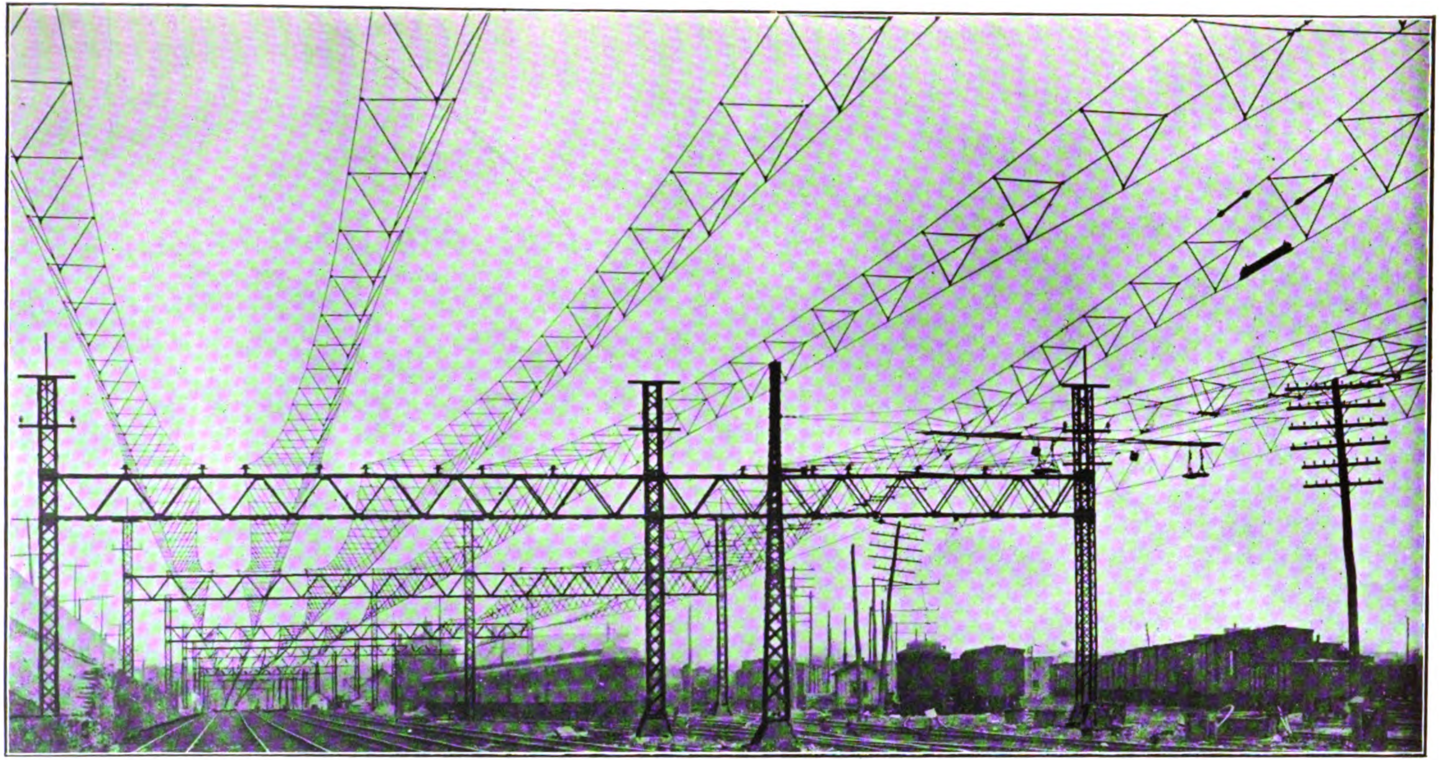

FIG. 10—Double overhead catenary trolley on New Haven Road. Four tracks and siding

(p. 1152)

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years important developments have taken place in direct-current motor construction which materially change any preconceived conclusions as to its limitations.

The first is the introduction of the commutating pole, which has practically eliminated commutator troubles, such as sparking, undue heating, and flashing over, so that even a four-pole machine, within a wide range of potential and load, runs absolutely black at the brushes. That this improvement has reached a high degree of commercial standing, despite very recent technical criticism and opposition, is evidenced by the fact that orders for nearly a thousand railway motors have been placed within the last two months.

This improvement makes possible the shunted-field addition to the series-parallel control of speed, the construction of motors for operation at much higher potentials, and the operation of two motors in series at double potential. The partial dependence of one motor on another when two machines are in series is not individual to this combination, for with single-phase alternating-current motors, especially of the larger capacity, the heavy currents required because of the low potential at which the motors are operated—200 to 250 volts—has led to permanent series or series-parallel connection of machines.

An especially important development is that illustrated by the gearless locomotives built for the New York Central Railroad, (Fig. 4) in which the hitherto invariable practice of maintaining a fixity of relation between the armature, or rotating part, and the field-magnet, or fixed part, has been abandoned; the armatures are mounted directly ont he axle, the field-magnets forming a part of the locomotive-frame, supported by its springs and hence movable with regard to the armatures. In this construction, therefore, there are no armature or field bearings. This locomotive is of the simplest type possible, electrically and mechanically; and when operating under conditions for which it is properly applicable it has not only the highest weight-efficiency, but the lowest cost of repairs of any direct-current machine, and much lower than is possible for any single-phase locomotive. It is structurally a natural high-potential machine on account of having but two poles.

Since the capacity of electrical apparatus depends upon the speed at which, with any magnetic flux, the armature conductors move, this gearless type of locomotive, if used for the slow speed and heavy torque required on freight service, can only

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be constructed with reduced weight-efficiency as compared with geared locomotives; but despite this handicap there are so many special advantages that it can be seriously considered even for this service.

Difference between direct-current and single-phase alternating-current motors. The present inherent differences between single-phase and direct-current motors may be briefly summed up as follows:

1. The input of current in one is continuous; in the other intermittent.

2. One has a single frame, the electrical and mechanical parts being integral; the other has a laminated frame contained within an independent casing. Hence there is not equal rigidity, or equal use of metal.

3. One has exposed and hence freely ventilated field-coils; the other has field-coils imbedded in the field-magnets.

4. One has a large polar clearance, and consequently ample bearing-wear; the other has an armature clearance of about only one third as much, and hence limited bearing-wear.

5. One is operated with a high magnetic flux, and consequently high torque for given armature-conductor current; the other has a weak field, and consequent lower armature torque.

6. One has a moderate sized armature and commutator, and runs at a moderate speed; the other, with equal capacity, has a much larger diameter of armature and commutator, and runs at a much higher speed.

7. One permits of a low gear-reduction, and consequently a large gear-pitch; the other requires a higher gear-reduction, and a weaker gear-pitch.

8. The windings of one are subject to electrical strains of one character; in those of the other the strains are of rapidly variable and alternating character.

9. The mean torque of one is the corresponding maximum; the mean torque of the other is only about two thirds of the maximum.

10. The torque of one is of continuous character; that of the other is variable and pulsating, and changes from nothing to the maximum fifty times a second.

11. One has two or four main poles only, two paths only in the armature, and two fixed sets of brushes; the other has four to fourteen poles, as many paths in the armature, leading to unbalancing, and as many movable sets of commutator brushes.

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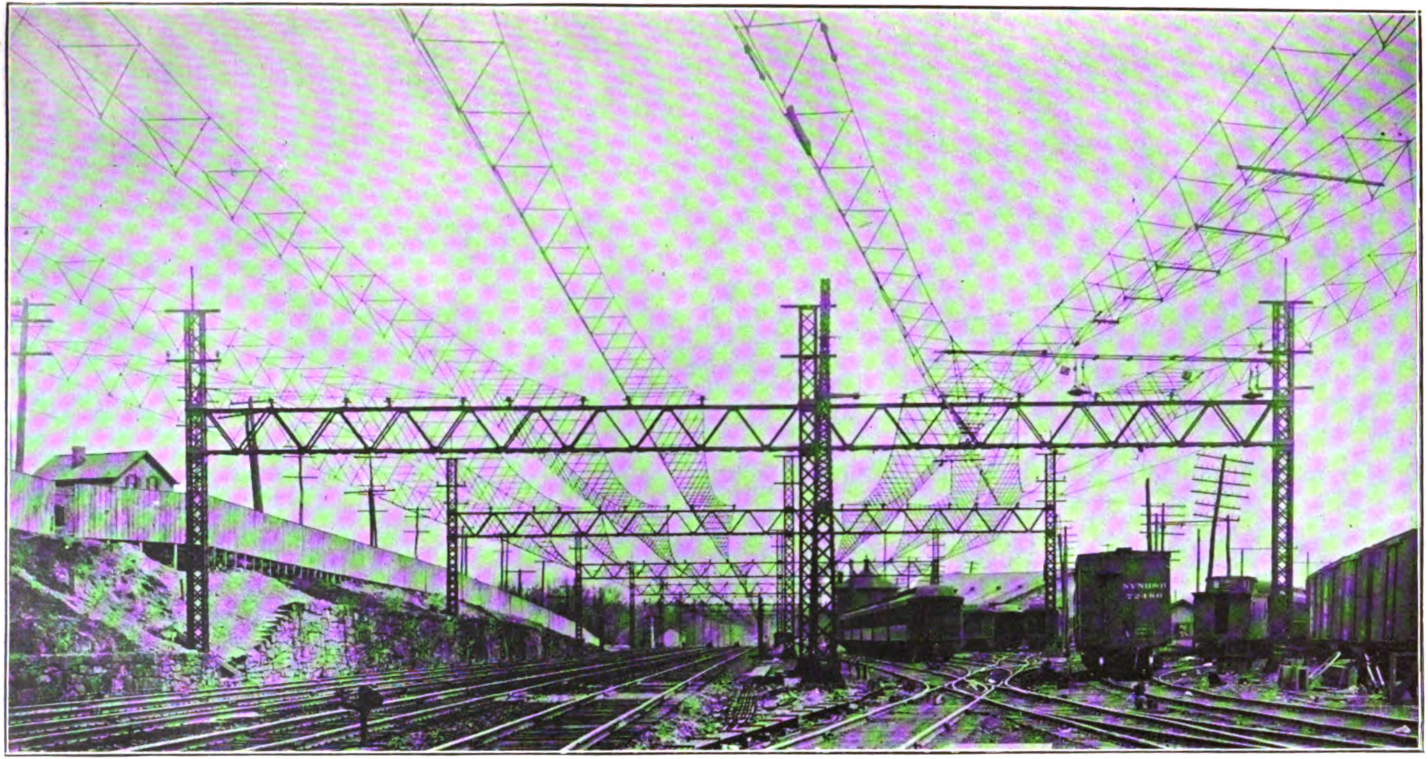

FIG. 11—Double overhead catenary trolley on New Haven Road. Four tracks and cross-over

(p. 1154)

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12. One can maintain a high torque for a considerable time while standing still; the other is apt to burn out the coils which are short circuited under the brushes.

13. In one, all armature-coil connections are made directly to the commutator; in the other, on the larger sizes resistances are introduced between the coils and every bar of the commutator, some of which are always in circuit, and the remainder always present.

14. In one the sustained capacity for a given weight is within the reasonable requirements of construction; in the other it is only about half as much.

15. Finally, the gearless type, with armature and field varying relatively to each other, is available for one, but this construction is denied to the other.

Consideration, then, of the characteristics peculiar to each class of motor indicate, not that the single-phase motor cannot be used, but that if adopted the weight or number, and the cost of locomotives or motors required to do the work must be much greater; that the depreciation of that which is in motion will be much higher; and that there will always be an excess weight of fixed amount per unit which must be carried irrespective of the trailing or effective loads. We must, therefore, in many cases be led to the selection of the direct-current motor, that motor which has the higher weight-capacity, the greater endurance, and the lower cost per unit of power.

Electric braking. Recuperation of energy to reduce the amount of power used, and to make the motors act as brakes to retard the acceleration of a train, has been a favorite project, and attended by many prophecies since the beginning of the electric railway industry. I confess to having been very early infected with this economic ambition. In fact, I demonstrated mathematically quite correctly and satisfactorily a good many years ago, before the Society of Arts in Boston, that if the Manhattan Elevated Railway of New York could be equipped electrically with shunt-wound motors whose speed-variation was effected partly by resistance in the armature circuit and then by variation of field strength, there would be a reduction of central-station capacity of fully 40% as compared with a system which did not use the motors as braking generators; and not only was there this theoretical reduction in capacity, but since every stopping train, and every train on a

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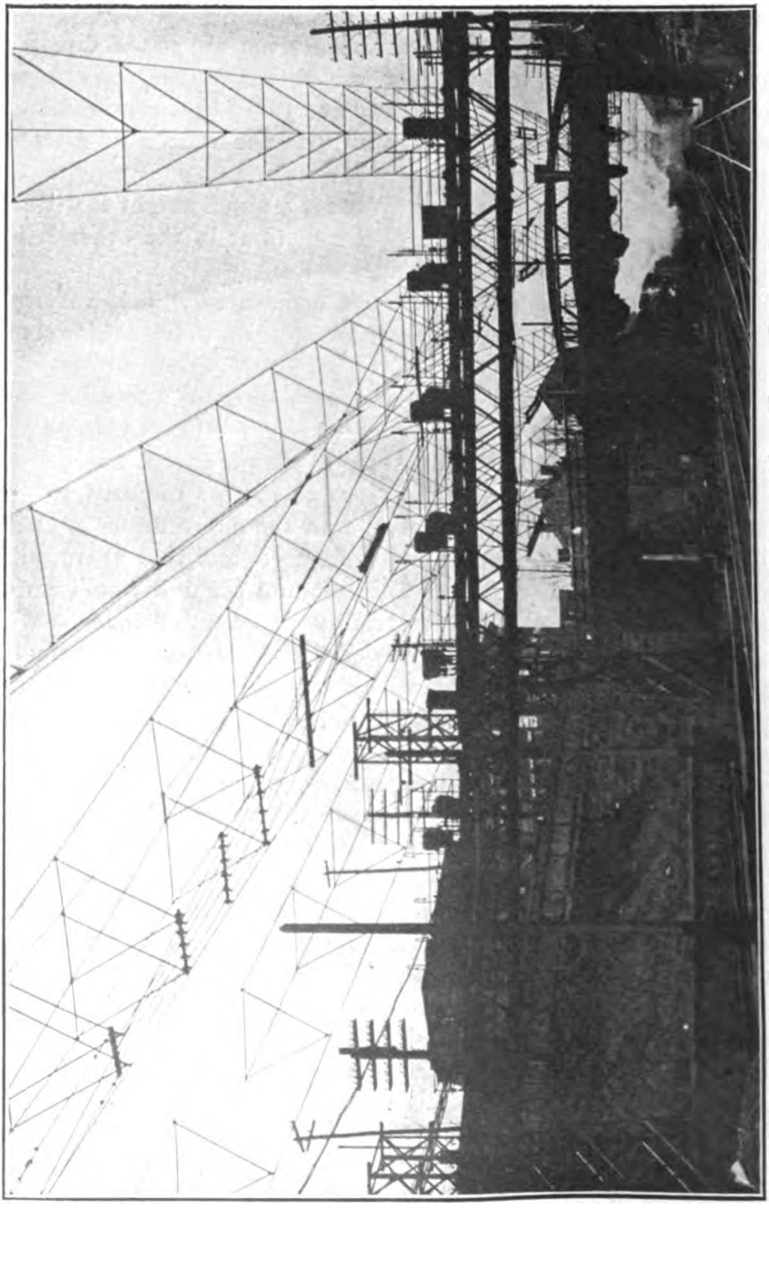

FIG. 12—Double overhead catenary trolley on New Haven Railroad
Cross-over, anchor bridge, and section switches

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down-grade was a moving generator there would naturally be materially less losses on the line. These facts were demonstrated practically by experiments carried out on the Thirty-fourth

FIG. 13—Double overhead catenary trolley on New Haven Railroad.
Depression under crossing highway bridges

Street branch of the elevated railroad for several months in the winter of 1885–6. But the system is not used to-day, despite its enormous possible saving of power and station capacity,

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because it required the use of shunt motors with their fine-wire field-windings, and hence necessary reduced capacity compared with the modern series motor; it required, also, a very exact equalization of the characteristic of motors and maintenance of like wheel-diameters, and an increase of motor-capacity and weight because of the double duty and consequent heating. Here again capacity has been an important and finally determining factor in motor requirements and practice.

On ordinary railroads the gradients are not sufficient to make it worth while to attempt any recuperation of energy; the acceleration due to any excess of gravity-coefficient above that necessary to overcome the friction of the train is usually welcomed. On mountain roads, however, electric braking may become an important adjunct, not because of power economy, but for safer operation. In any case, simplicity of application and absolute reliability of action are first essentials.

There are two general methods available: one, in which the energy of the descending train drives the motors, acting with shunt- or independent-field characteristics, at an aggregate potential above that of the line at the rail, and sending current back into the line; another in which the motors are disconnected from the line, and driven as self-exciting generators on a closed circuit, as much of the energy of the descending train as desired being used up in heating rheostats.

The first method is dependent on the line, requires external excitation of the field-magnets, and where direct-current motors are directly connected to the line, two armatures should be thrown in series if the power to slow the train down to or below its ascending speed on heavy grades is desired. This is because the excitation of the fields is carried to saturation on ascending work, when the motor electromotive force is much less than that of the line plus the drop on the supply conductors, and permits of no further increase of flux to raise it. Such independent excitation of fields should be through a motor-generator set to get the current of low potential in large volume necessary for the series fields.

This method is, of course, possible of application, and will give a range of control of speed from about the mean speed on ascending grades to double that speed; but it will be with inequality in heating of the armatures and the fields, the latter running cool, and the former practically at their average maximum.

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It is not practical to set the control for a given down speed and then to vary speed by the air-brake, for the braking power of the motors is measured by the relation of their potential to that of the line, which is variable. To be effective, this potential must be raised sufficiently above that of the line, wherever a locomotive may be, not only to send back current, but current in considerable volume over the conductors intervening between it and such other locomotives or stations as may be able to take up the energy thus created. The motors are therefore under a constantly varying condition, and are also subject to excess potential strains. Application of the air-brake to slow down a train would under such circumstances reduce or destroy the braking power of the motors unless their controllers were simultaneously moved. In fact, such air-brake application could readily convert the machines into motors taking current from the line, and hence put double duty on the brake-shoes.

The second method of braking is to use the motors without disconnecting the field and armature circuits from each other, simply closing them upon themselves, and varying the resistance in circuit, the reversers on down grade being set for backward movement. This method requires no change in the organization of the machine, puts equal duty on armatures and fields, as in ascending grades, and the duty on the armatures being considerably less than in the other method of braking they will heat much less.

This method, if provision be made for moving the controller, is independent of the line, and permits of the most complete variation of speed, from the highest permitted to the lowest at which it may be desired to operate, without any use whatever of the air-brake, unless desired, and without in any manner interfering with the application of the latter, although, of course, to get the best effect, both motor-controller and air-brake should be used with regard to each other. There is, however, no possibility of the application of the latter entirely destroying the braking power of the motors.

This latter method of braking does not depend upon line supply, nor require the interposition of any motor-generators, and is therefore more direct and reliable. Another fact of importance is that the aggregate motor potential strains are less. Provision for both methods of braking, although possible, is not advisable because of the introduction of too great a variety

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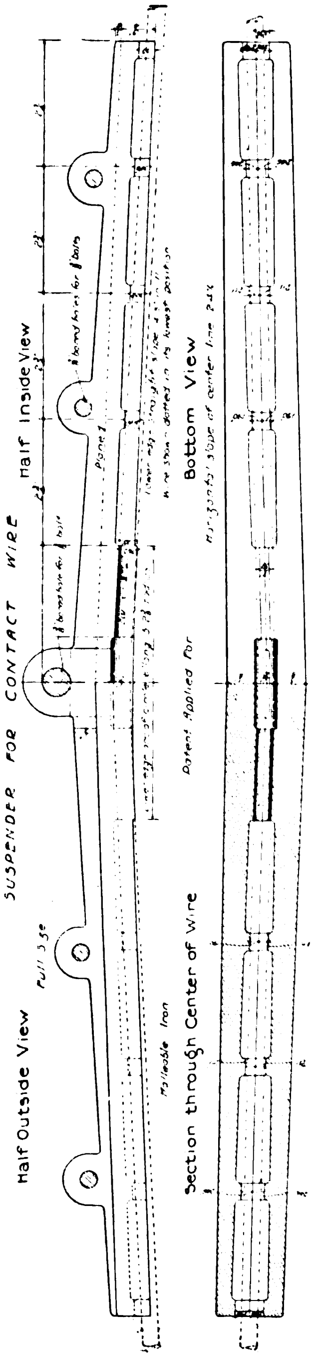
SUSPENDER FOR CONTACT WIRE
Half Outside View
Half Inside View
Bottom View
Section through Center of Wire
Malleable Iron
Patent Applied For

FIG. 15

of apparatus and methods, which may give rise to confusion and accident, and which in all cases of railroad operation should be avoided as far as possible.

With polyphase motors kept in connection with the line, the braking effect is very similar to that of pure shunt motors, and the excess of down speed is very small. It is doubtful, however, whether with the varying grades and curves of our mountain roads it is desirable to run down-grade at an approximately fixed speed, but rather it seems likely that the existing practice of speeding where the grades and curves are light, and reducing the speed where the grades are heavy and the curves are sharp will remain the preferred practice.

Self-exciting braking is impracticable with polyphase motors.

Comparison of direct-current and alternating-current braking. On the general subject of braking it should be pointed out that with direct- or continuous-current motors there is always a residual magnetism in the fields because of their construction, and the fact that the exciting current never changes direction. Such machines, therefore, can always promptly build up automatically when properly closed upon themselves and the reverser is set in the proper direction.

A similarly effective method of braking has been claimed for motors operated by single-phase alternating currents, but it would seem that in this case there is not the same degree of reliability. In such motors the field is laminated to the last degree to cut down heat-losses and to increase the capacity; it will hold but little residual magneti m under any circumstances, and furthermore the field is excited by a rapidly varying alternating current. It is therefore possible that at times the field will be nearly inert, and comparatively slow, with its low-turn winding, in building up, or possibly the field may be entirely inert, and may refuse to build up at all. There seems, therefore, no certainty whatever that a single-phase alternating-current motor, disconnected from the line, and without any other exciting source, will, when closed upon itself, always build up into a braking dynamo.

Aside from the ordinary objection of having such a possible failure, the consequence might be serious should it be necessary suddenly to call upon the machines to brake; as, for example, when getting underway, or when slowly ascending a grade there should be a failure of current and the train begin to back down before the air-brakes were applied, or in case for any reason they should not be promptly available.

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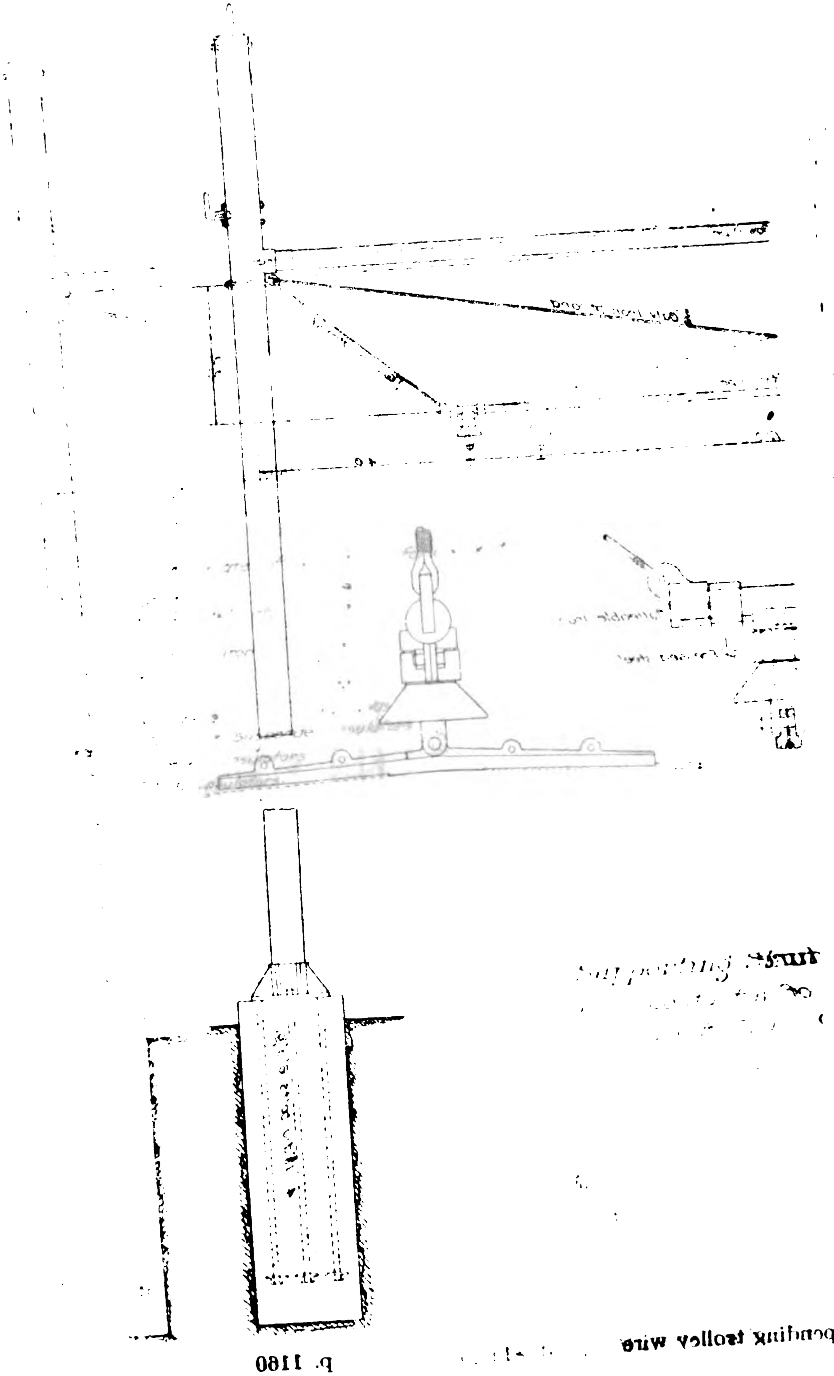

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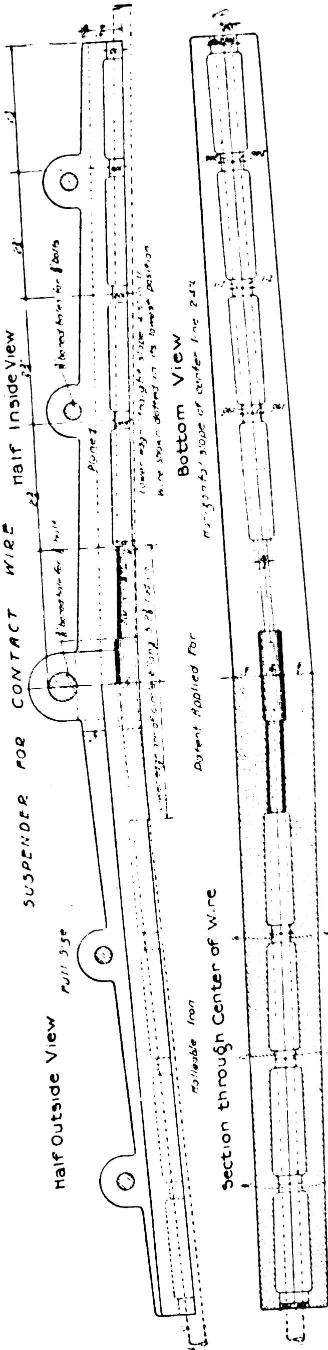
Suspender for Contact Wire
Half Inside View
Half Outside View
Full Size
Malleable Iron
Bottom View
Patent Applied For
Section through Center of Wire

Fig. 15

All things considered, reliability and simplicity of operation dictate the use of the self-exciting method of braking with the direct-current motor, which lends itself to that purpose in the highest degree.

Extent of electric braking. However theoretically desirable it would be from an economic standpoint to utilize the energy of a descending train to generate current available for partial propulsion of trains moving on up-grades, it is to be borne in mind that the localized braking of an electric locomotive is not intended to, nor can it entirely replace air-braking; it is proposed primarily for the purpose of eliminating certain existing troubles unavoidable in connection with air-brakes when used continuously on long down-grades.

In trains made up of the average run of freight cars there is a non-simultaneous action of the air-brakes, and often, if after long continued application the brakes are released for a brief time so as to re-charge the train-pipe, the front end of the train being unbraked will surge ahead, and the rear part will for a brief time be held back by the non-released or partially released air-brakes, resulting in a parting of the trains.

Another serious trouble, overheating of brake-shoes and wheel-rims, leading to breakage of parts on account of expansion or sudden chilling, cannot well be avoided where there is such a continuous application of air-brakes as is required on free movement of freight trains on long grades; this is a difficulty which it is best to avoid by supplementing the air-brake by other braking means not dependent upon brake-shoe application.

The objections cited will be largely removed if the duty on air-brakes can be materially reduced, and sometimes entirely relieved. Electric braking on the method I have indicated will accomplish this, and it seems wise normally to divide the duty between electric and air-braking. For that reason I will give an illustration of the duty on the motors, as this will have a direct bearing upon the capability of the radiation of energy in the form of heat from the rheostats in circuit.

Suppose a 700-ton train operates on a grade requiring tractive efforts per ton of,

For lifting	25 lb.
For traction and curves	8 "
Total	33 "

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On down movement, 17 lb. only will be available for acceleration of speed, which must be taken up by braking in some form.

If divided between electricity and air there would be required from the locomotive:

Average retardation per ton	8.5	lb.
Total for 700-ton train	5950	"
Foot-tons per minute, at 20 miles	5192	
Equivalent electrical rate	235	kw.
Dissipated in rheostats at 90% machine efficiency	212	kw.

which would be a light duty for four motors and rheostats, and would leave ample margin for them to take the full braking effort up to the skidding of the wheels whenever it might become necessary.

Working conductors. Whatever motors are used--and all the principal types will be used—there is a variety of methods of construction and use, especially as applied to locomotive building, and alternate methods of current supply and use.

Generally speaking, conductors may be divided into two classes; flexible or rigid overhead, and third-rail, One wouid suppose from many references, and some of the arguments which have been made that direct-current systems are essentially and necessarily dependent upon the third-rail and that the overhead trolley is a thing individual to, and has been developed for alternating-current operation only. This impression should be corrected, not of course for the information of engineers, but because this somewhat erroneous idea is in danger of being accepted as a fact by non-technical men.

The overhead system has been a distinctive feature of all electric roads operated by direct current since the days of the historic Richmond road, with the exception of those using the third-rail; and until recently the only practical modification has been the somewhat limited use abroad of the sliding bow or roller in place of the grooved trolley-wheel. This latter, although used with high speeds on interurban roads, is unfitted for trunk-line operation, and where overhead trolley wires are used the long collector will probably take its place.

Physically, the overhead trolley is not individual to any particular system; practically, its use depends upon the amount of current which has to be collected. If at low potentials, then it must be either strongly reinforced, and there must be a plurality of contacts, or if these are diminished the amount

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of current to be collected must likewise be reduced and the potential raised. In the abstract, therefore, the possible use of the overhead trolley, no matter by what system, is a question of allowable operative potential, and the amount of current which can be practically collected.

Identified as I have been with the development of the overhead trolley, I cannot but feel a pride in what has been accomplished with it, nor shut my eyes to a certain fascination in the conception and knowledge that there may be transmitted over great distances, and taken at will from almost a spider's

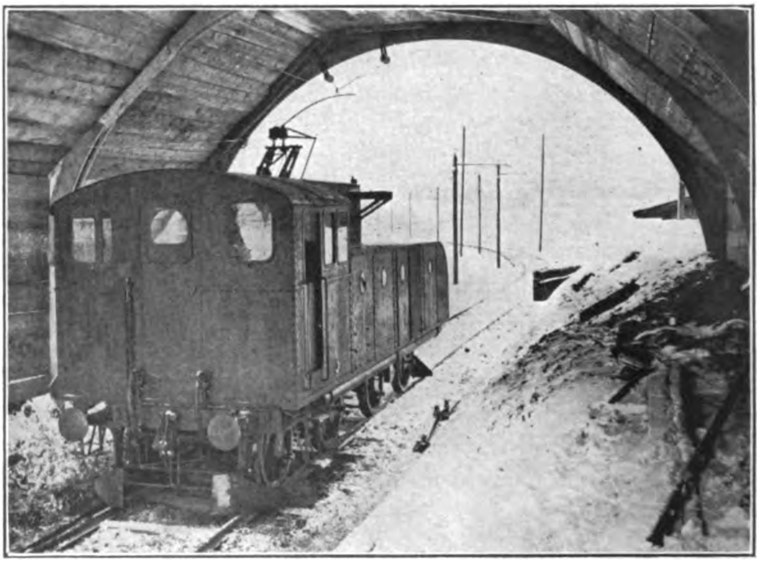

FIG. 16—Oerlikon trolley in tunnel—single-phase M. G. Locomotive

web, an enormous power. An ardent advocate for years of the use of higher potentials, and fully aware of the limitations of the direct-current standard which has existed so long, I believed for a long time in, and advocated the use of the overhead trolley as the only practical working conductor for potentials above 1000 volts.

Until recently the invariable practice with overhead construction has been to use a flexible wire supported at comparatively long distances on tangents, with pull-offs at curves, and easily yielding to the pressure of a trailing trolley. This

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is the practice which characterizes not only direct-current trolley operation, but has also distinguished practically all operation abroad where single-phase or polyphase currents have been used. The introduction of high tensions has, however, now made it necessary to provide by additional supports against the possible breakage of the trolley-wire. This had led to the introduction of catenary construction, the catenary being either single and supporting the trolley at frequent intervals, or double to prevent lateral swaying. In the former case, the

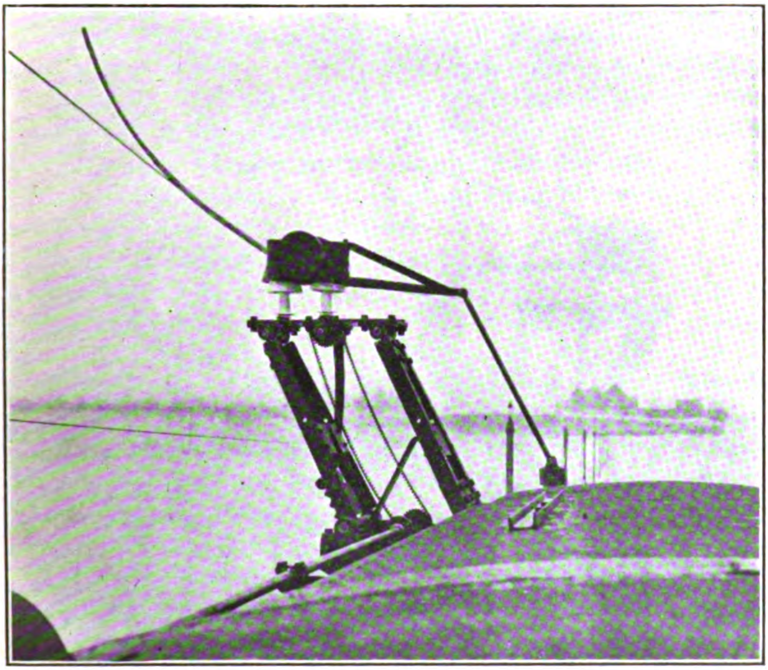

FIG. 17—Oerlikon trolley—over-contact

trolley is only partly flexible, and in some cases the support has been supplemented by an intermediate catenary, as on the Blankenese-Ohlsdorf railway, (Fig. 9) where greater flexibility of the trolley-wire itself is insured by loosely suspending it from the lower member of the catenary instead of making the latter the trolley-wire, and providing for varying the tension. In other cases it is to some extent maintained by having less frequent supports, and also by introducing a movable part at the suspender.

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The most recent and extended application of double-catenary construction is that on the New Haven road for use with its single-phase locomotives (Figs. 10-13). Here a trolley wire is put under high tension, and is supported at frequent intervals by solid clips attached to rigid triangles, in turn secured to galvanized iron wire cables carried on insulators on the top of bridges which span the tracks at intervals on tangents of about 300 feet. The catenaries are drawn together between the spans so

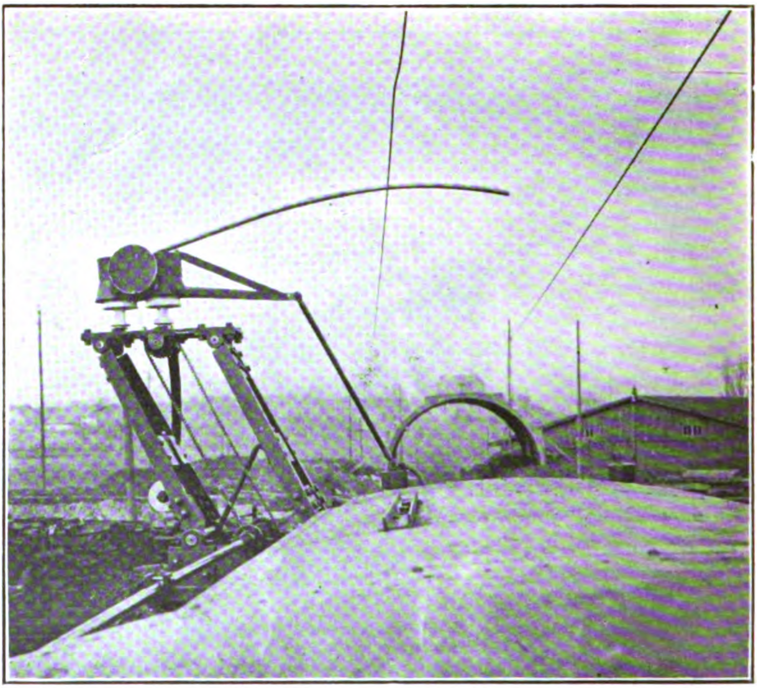

FIG. 18—Oerlikon trolley—under-contact

as to give the utmost rigidity to the whole system, the intent being to maintain the trolley-wire as nearly as possible in one plane. At cross-overs and sidings (Fig.11) the supporting triangles overlap, and the angle between the junction and the trolley wires is filled with additional conductors, more readily to insure safe passage of the vertically moving sliding contact which has been adopted. At intervals of about two miles the trolleys are sectionalized at anchor-bridges, (Fig. 12) where are provided the

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necessary switches for cutting out sections, and for looping to extra supply conductors.

Among the innumerable trolleys which were tried in early days was a roller of considerable length, mounted at the end of a rod having a vertical telescopic motion in a tube carried on top of the car, and pressed against the wire by a spring in the tube. This was abandoned in favor of the trailing trolley which would more readily follow variations in the trolley-wire. The modern pantograph is an elaboration of this early idea, and has a very much greater latitude of vertical movement. It consists of a sliding or rolling contact, which forms the upper number of a light, yet strong collapsible structure maintaining an upward spring pressure. The theory of this system of collection is, of course, that a locomotive normally moves between two parallel planes, on one of which it runs and from the other of which it collects current, and that the ordinary motion of the contact will be inappreciable. This assumption is, however, modified in practice. The collectors are carried normally 22 feet above the track on a superstructure (Fig. 7) which must respond in some measure to track irregularities, and which has considerable inertia and some friction. There is a drag because of friction against the trolley-wires, and wind-pressure due to motion of the locomotive. This upward pressure must necessarily be changeable because of variation of angle, friction, and the resultant motion. To maintain contact it must rise and fall. When travelling 70 miles an hour it passes supports which are more or less rigid nine times a second, and between these supports the trolley-wire, no matter what the tension, will be convexed upwards. As the collector approaches any suspender the pressure will normally considerably increase, and, as it leaves it, diminish. The practical question arises, whether, considering all the forces acting on it and its inertia, it can satisfactorily respond in addition to other requirements to a double change in vertical direction nine times a second. If contact depended upon the whole structure of the pantograph moving thus rapidly some trouble might be anticipated, but possibly the elasticity of the upper part will prove sufficient.

It is interesting to note that Mr. Joseph Mayer, the former chief engineer of the Union Bridge Company, in a paper read before the American Society of Civil Engineers, and also in several other communications, has given a great deal of thought to the question of overhead construction, and has made elab-

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orate calculations of strains involved. His conclusion was to the effect that no trolley wire put up under high tension, and supported in the rigid manner provided by the present catenary, offered either a sufficiently safe or economical method of construction, and he was therefore led to the development of two departures in practice. The first was the use of an overhead rigid iron rod 1.25 in. in diameter, suspended by catenaries, and provided with extension-joints; the second (the first method apparently having been found too expensive) is a method of flexibly supporting a trolley-wire at long intervals from inverted pivoted suspenders, which provide a support for the various section-lengths according to the end-slopes (Figs. 14, 15). The suspender grips the trolley only along the center, and then it opens out in large radii to give a graduated resistance to both vertical and lateral deflection. Mr. Mayer's analysis of conditions, the mathematical deductions, and his proposed remedies as illustrated by his detail plans, well merit serious consideration.

An ingenious method of making contact with an overhead single trolley-line is that developed by the Oerlikon company under the direction of Mr. Huber (Figs. 16, 17, 18). In this system the trolley is stretched with comparative rigidity on top of insulators supported on posts alongside the track, with cross-overs where needed. In place of the ordinary wheel and bow trolleys, a curved hinged arm of fair length, and sweeping over nearly one half a circle in a plane transverse to the line of track, is supported on insulators on the side of the car. Normally, this bow rests on top of the wire, pressing lightly on it, and thus avoiding the under formation of icicles. On cross-overs and in tunnels, where the trolley-wire is carried over the track, the arm swings toward the center of the car, and is depressed, making contact progressively from the top around to the side and then underneath the trolley-wire. In addition, the saddle which carries the bow is movable laterally, increasing the radius of action, Of course two bows can be used. I believe that in some of the experiments a roller has been tried. Two difficulties present themselves; one the fact that the wire is pressed down from the top, the strain of the weight being added to by the pressure of the contact bar, which can be, and I believe has been on one test minimized by having the wire supported by and above two catenaries, just the reverse of the New Haven practice; the other objection is that at cross-overs the trolley-wire is very close to the top of the car.

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The system is somewhat similar to one originally proposed in my earlier trolley work, where two vertical rollers with uni-

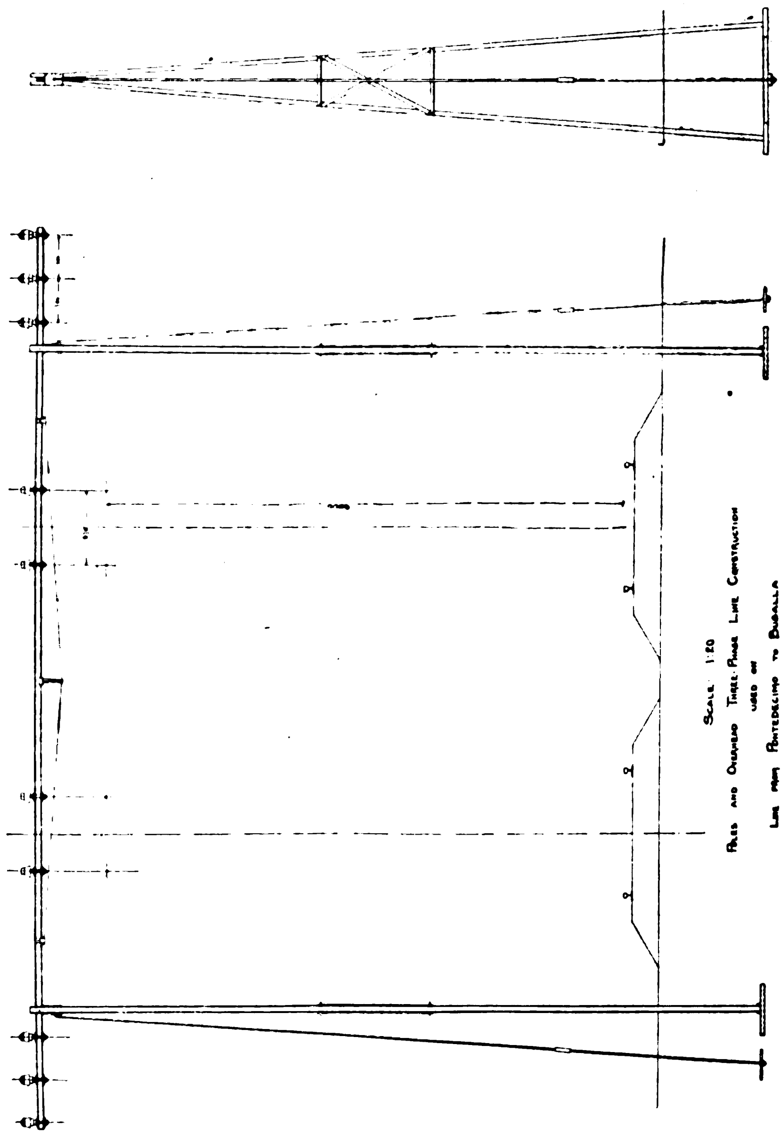

Fig. 19—Ganz overhead trolley support

versal flexible support made contact, one on each side of a trolley-wire, and at crossings one was deflected below it. This was not put into practice.

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A very neat structure for the overhead trolley, whether of the ordinary or catenary suspension, is that designed by Mr. C. de Kando of the Ganz Company, (Fig. 19).

The alternative type of working conductor is the third-rail. already adopted on about forty roads, some of considerable extent, most of them with heavy passenger traffic, and operated under

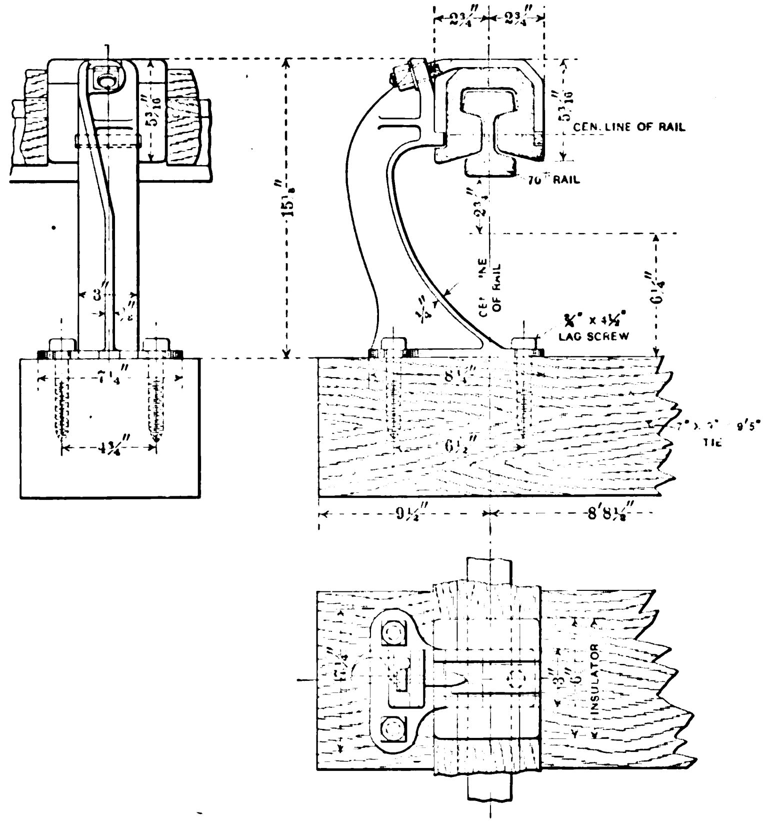

FIG. 20—Details of Wilgus and Sprague protected third-rail

greatly varying conditions. A large proportion of these roads have used the ordinary type of top-contact rail, carried by insulators on the ties, sometimes entirely exposed, and again partly guarded by side boards, as on the Manhattan Elevated, or by a wooden shield carried by yokes from the rail itself, as on the Interborough. While this is the simplest form of third-rail

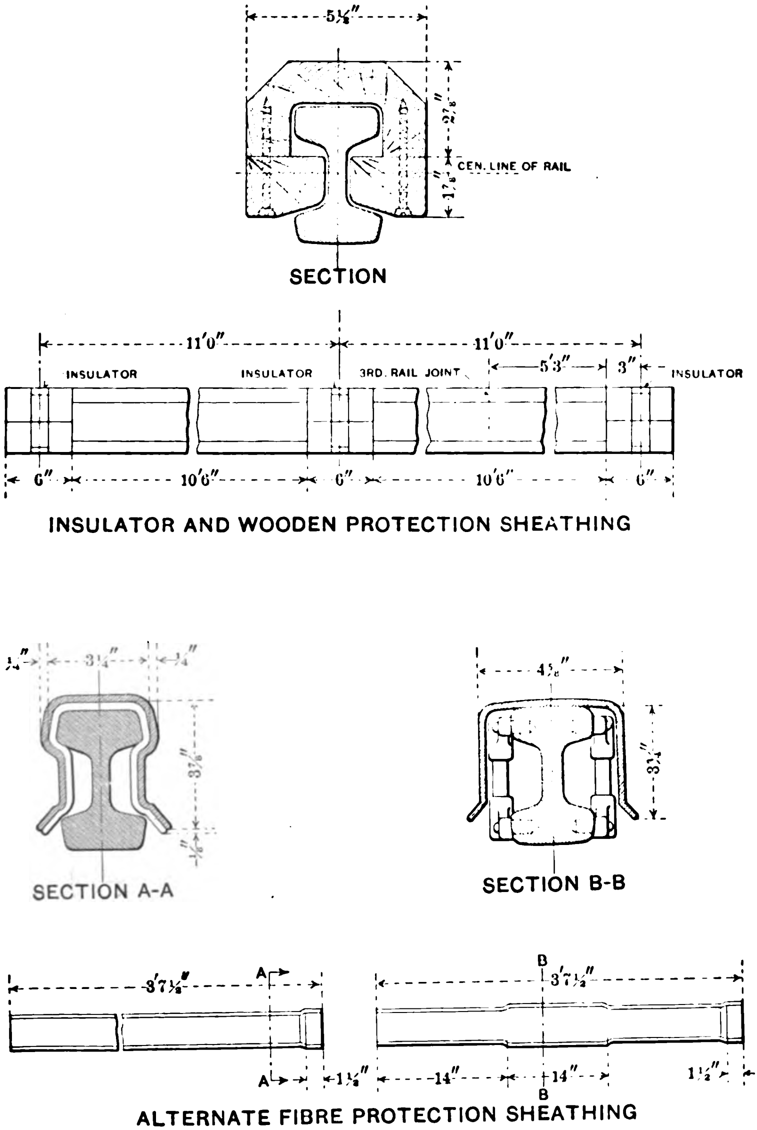

Fig. 21—Details of Wilgus and Sprague third-rail

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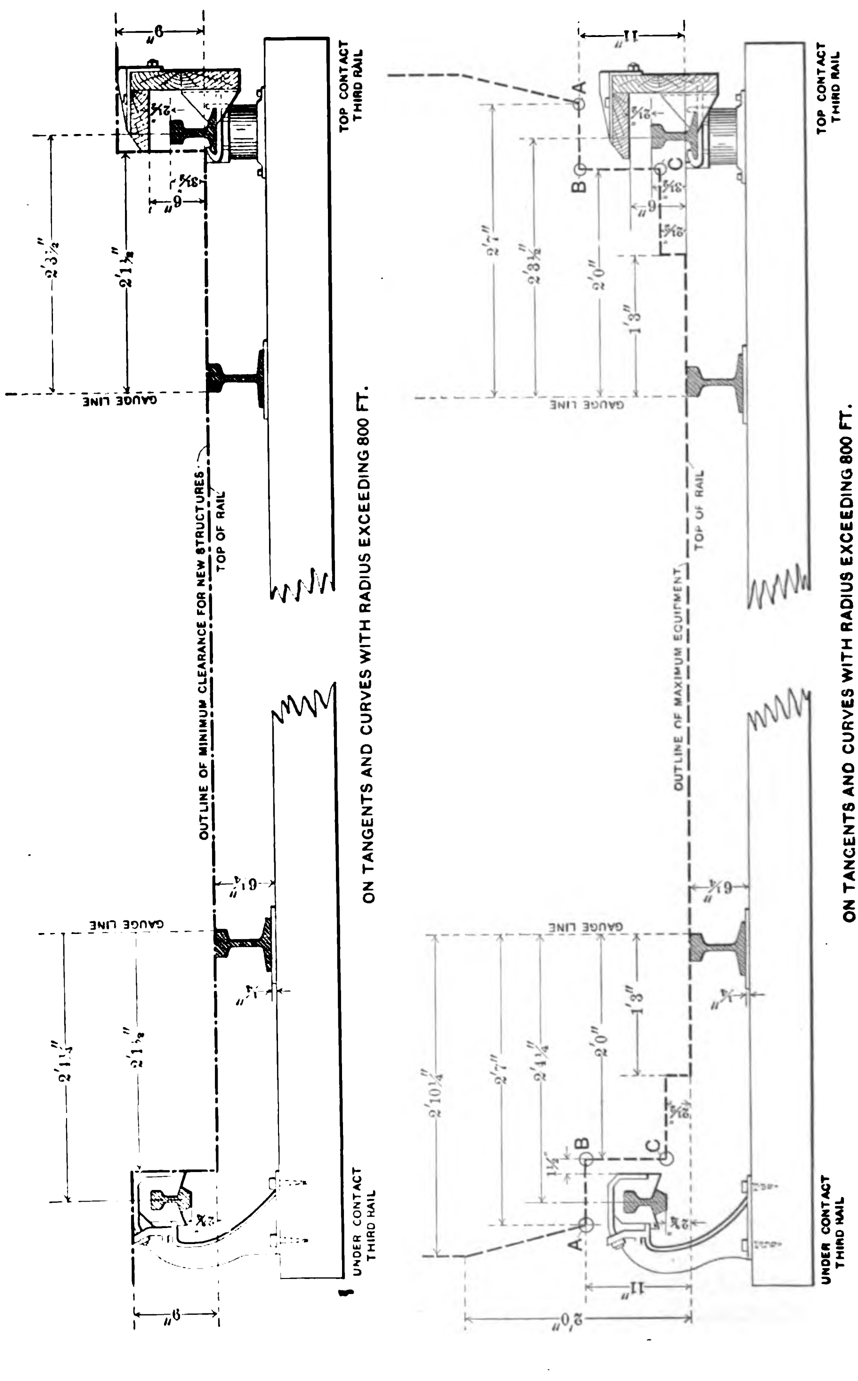

FIG. 22—Clearance diagrams—equipment and third-rails

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construction, and has given good service for years, it has certain disadvantages. If exposed, it is a constant menace, especially in yards; and even when guarded it cannot be wholly protected from snow and ice. The lower part is only about four inches above the tie, while the holding-clips generally used reduce even this clearance, so that the danger of grounding from accumulation of wet snow, ashes, and from flooding is increased. In the latter case, over-all flooding has the whole rail-surface for leakage.

These various objections led to the abandonment of the top-contact rail in connection with the New York Central work, and the development by Mr. Wilgus and myself of a new type—an under-contact sheathed rail—supported by insulators from brackets carried on the ties, and with the body of the rail about nine inches clear (Figs. 20-29). The results have been so satisfactory that this type of rail has been adopted for the 285 miles of trackage under electrification, as well as on a number of other roads. It differs from the top-contact rail in that it affords far greater safety, more certainty of continuous operation, and can be used with higher potentials.

The structure consists, briefly, of a series of iron brackets carried on the ties, to the tongued vertical face of which are clamped non-charing moisture-proof insulator-blocks which loosley embrace the head of the rail. Intermediate between the insulators the rail carries an insulating sheathing, which embraces the head and reaches down nearly to the bottom face of the rail, but extends outward from the web to form a petticoat protection against snow and sleet.

The position of the rail depends primarily upon the clearance requirements. To meet those of ordinary trunk-line rolling stock, the bracket-height is made so that the under-contact surface of the third-rail is 2.75 in. above the surface of the traffic rail, and the center of the rail 27.25 in. from traffic rail gauge line (Fig. 22). On account of using the under-contact, the body of the rail is of course considerably higher from ties and ballast than that common in top-contact rail construction, being about five inches more.

On crossings, the horizontally extending flipper-shoe, pressed upwards by a spring, lifts and clears the traffic rail by a fairly safe margin. At switches, to accommodate the lateral displacement of a locomotive when taking the siding, while not reducing the clearance from the protective sheathing on the

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straight track, the lower head of the rail is specially formed; similar construction is necessary for engaging the shoe when entering a straight track from an angle.

For moderate potentials, say of 600 volts, the two halves of the insulator-blocks are alike, but for the higher potentials the inner insulator-block, that is, the one next to the face of the bracket, is extended so as partly to shroud the head of the bracket. The sheathing between the insulator blocks, depending upon local conditions and price of materials, as well as potential used, is formed of three wooden strips, one grooved on the under side

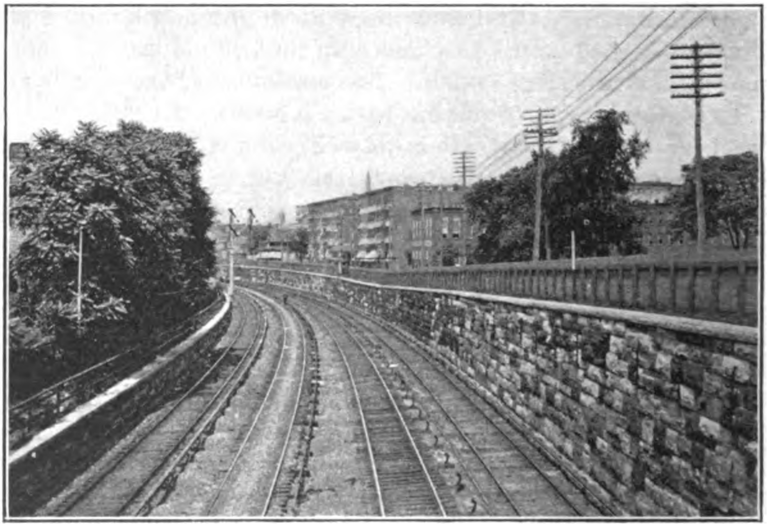

FIG. 23—Three states of third-rail construction, New York Central

and enclosing the head of the rail, and the other two, attached to and dependent from it, reaching in towards the web of the rail. Where good wood is not available, an alternate protection, costing about the same and having a higher electrical resistance, although not quite so good a mechanical one, is a semi-flexible shell of indurated fibre conformed to the rail-section.

To get the highest protection both mechanically and electrically, the two methods of sheathing can be used, or in place of the inner sheathing of indurated fibre the wood sheathing can be carried slightly removed from the rail-surface by non-

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hydroscopic saddles; this leaves an air-space between the wood and rail, prevents warping, and affords the necessary physical support for rigidity.

At passenger stations, where special precaution may be deemed advisable, and in freight yards the double protection can be used, and any required thickness of insulation adopted without reducing clearances by reducing the cross-section of the rail at these points. The conductivity will of course be made up by the number of rail-circuits in parallel at these points.

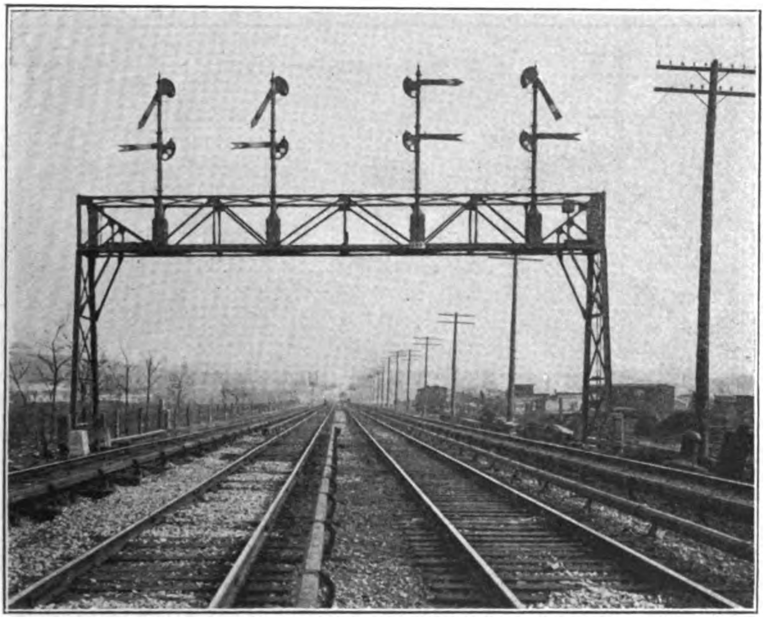

FIG. 24—Protected third-rail on 4-track division, New York Central

This protection is of such character that passengers, as well as employees in the normal discharge of their duties are fully protected. In sleet-storms none reaches the contact surface, small icicles only forming at the edge of the petticoats, and these are easily broken off by the passing shoe.

Of course there is no packing of snow between protection and contact rail, and the increased distance from the ground reduces the tendency to leakage. An accidental advantage is a reduction of the tendency to creep and buckle because of less abrupt and wide changes in temperature.

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General comparison of working conductors. All working conductors are in many ways objectionable, but since they are a necessary connecting link between the source of supply and the motors, some comparisons may be made of the two kinds, the under-contact, protected type of third-rail and the overhead trolley, as affected by construction and operation.

The third-rail is an inert structure, it can be aligned accurately with the track, is not under strain, and its expansion can be readily taken care of. The overhead trolley is necessarily a

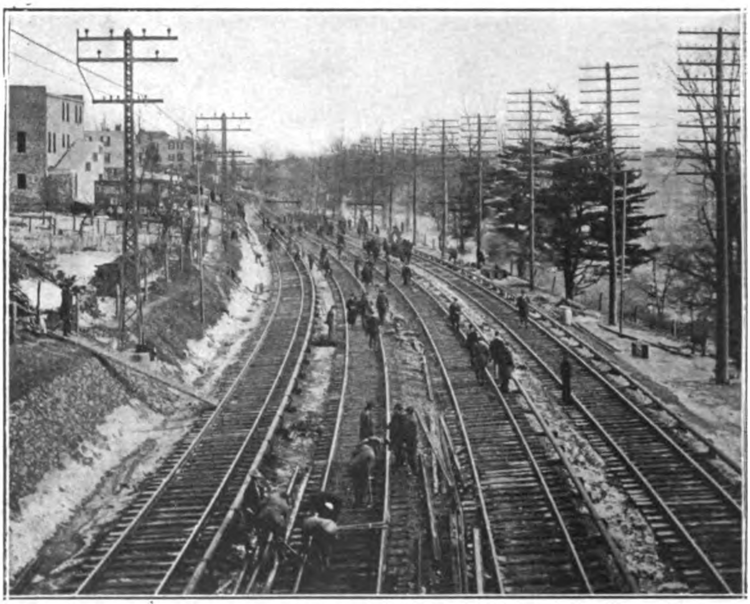

Fig. 25—Third-rail reconstruction after wreck

system under strain, and where permanency is desired and high potentials are used it must be carried by one or more catenary cables, which on roads of high curvature makes the construction more difficult. Its alignment in the latter case does not correspond with the line of track, and as ordinarily constructed it is subject to extreme variations of tension on account of weather changes.

The third-rail offers some hindrance to the ordinary maintenance of track; but overhead construction is inelastic, and the laying of additional tracks, or changes in grades or alignment

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require radical and expensive alterations or additions in permanent overhead structures.

Derailments will crush one form of conductor to the ground, forming a short-circuit which will cut off the section; but they may also knock down the supporting structures of the other, and, where there is a plurality of tracks, put them all out of service.

In wrecking, the third-rail offers some obstruction to the

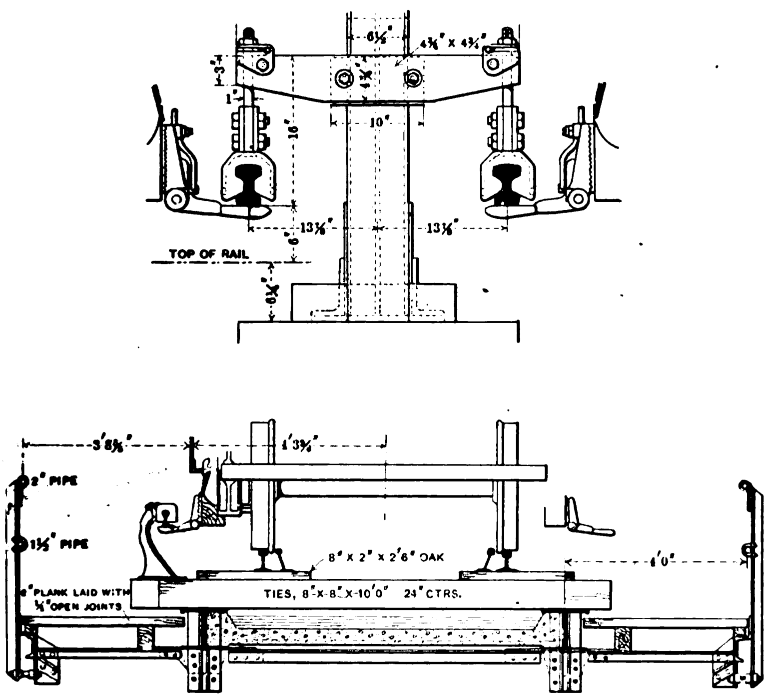

Fig. 26—Details of Wilgus and Sprague Protected third-rail on Philadelphia Rapid Transit Railway

throwing of the equipment to one side; but on the other hand, overhead conductors may interfere with the operation of the crane-booms of the wrecking car.

Where there are two or more tracks snow cannot be piled up between them if the third-rails are located there; but on the other hand, overhead conductors are a source of danger to train men, to snow-shed and tunnel repairers, and in the open are subject to troubles of sleet formation.

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The third-rail will oftentimes be covered with snow, but is unaffected by sleet. Very thorough tests made in connection with the New York Central work show satisfactory operation, not only in sleet-storms but with the rail buried in snow. Additional depth should not add much difficulty. With regard to frogs and switches, there are no problems which cannot be solved with this type of third-rail, with an occasional overhead section, and any required amount of power can be collected at operative speeds.

On western roads, where a rotary snow-plough is used, over-

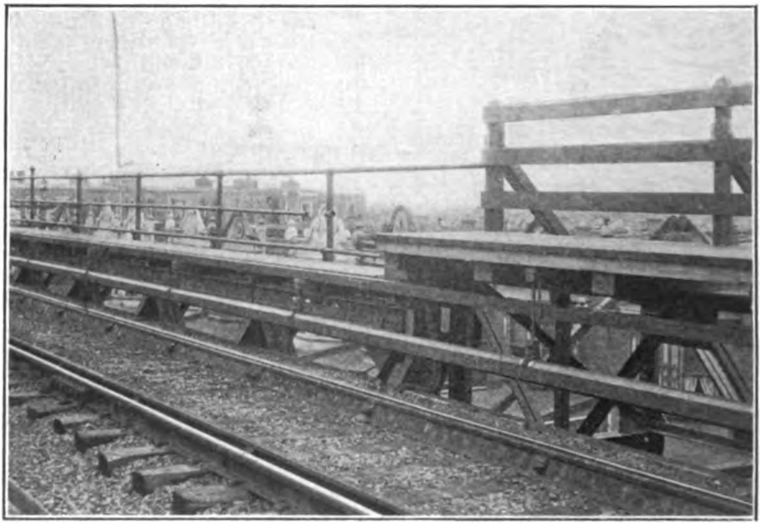

FIG. 27—Protected third-rail suspended from above, Philadelphia Rapid Transit Railway

head conductors and the supporting insulators, especially in yards, will be subject to a heavy bombardment of snow, ice, and refuse, with possible resultant breakage, and the under sides of the umbrellas of the insulators will be often filled up with wet snow.

As to danger to passengers or employees, this is largely overcome where the under-contact third-rail is properly protected, and is designed with due regard to equipment clearances. With an overhead high-tension trolley, there is, on trunk railways, where there are overhead street or highway bridges, tunnels, and snow-sheds, great possibilities of danger because of rearing equipment in case of derailments or collision, and the physical

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necessity of often bringing the trolley within a short distance of the cars.

Then there are corrosion and soot deposits when steam and electric operation are maintained over the same track. Where the steel supporting bridges also carry signals, as is proposed in some cases, there is increased danger to men engaged in cleaning, painting, or repairing overhead structures, and taking care of signals; and when spanning two or more tracks there is a possible interception of the train operator's view of signals because of dips in the railroad grades bringing overhead bridges

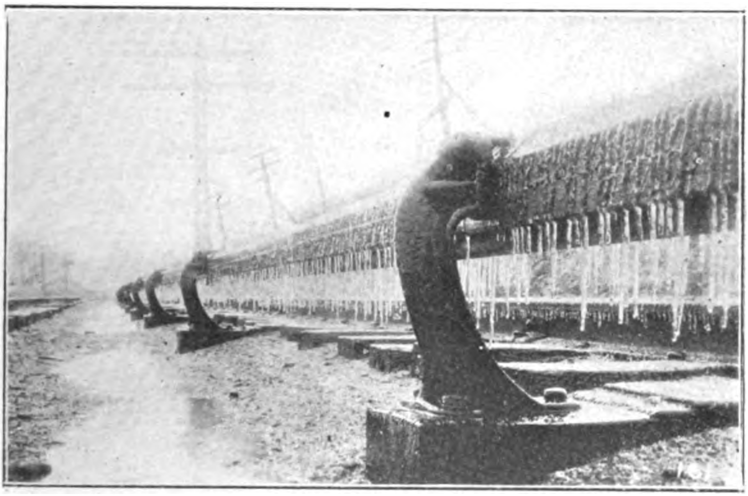

FIG. 28—Protected third-rail after sleet storm

in front of the semaphores, which likewise may be made less distinctive if they have truss members for a background.

In the matter of inspection, that of the third-rail can probably be carried on by the regular section hands, and ordinary repairs made without interfering with traffic. Repairs of an overhead system on a main trunk-line present some special difficulties. It will often require judgment and experience to determine just where trouble may exist, and in any case that particular section of the line must be absolutely cut out and made dead. If the repairs be other than at a rigid cross-suspension, it would seem that they would have to be made from the top of a structure. running on, and for the time being occupying the rails, and

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propelled by its own power. The old practice common to street overhead trolleys is of course unavailable; there a construction wagon can drive on to the track and off again at will, and the line even while alive can be readily repaired, but a practice possible with 600 volts would probably be fatal when attempted with the very high potentials now obtaining in single-phase operation.

In this latter system it seems vital in the interests of general safety that every crossing bridge, and every supporting structure should be mechanically and permanently connected with the

FIG. 29—Protected third-rail buried in snow

return circuit of the rails, to avoid the possibility of such structures being in partial or complete contact with the overhead conductors and not absolutely grounded, and at all crossings and highways both the catenaries and the trolley-wire should be thoroughly shielded from either accidental or wilful interference.

The time-honored tickler in universal use on steam railways to warn freight brakemen of the proximity of highway crossings, bridges, and tunnels seems unavailable with an overhead system; because if it did not catch in the pantograph collector it would be an ever present menace not only in wet but also in dry

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weather, because of the possibility of it coming in contact with the overhead line.

Where single-phase alternating currents are used, the magnetic and static inductive effects on telephone and telegraph circuits cannot be ignored, nor the danger of interference with signal systems disregarded.

The attitude of city authorities may in time raise effective obstacles to the use of overhead wires except where all crossings pass beneath the line of the road, and will I think, ultimately require new third-rail construction to be fully protected—even although on a private right of way.

Relative direct-current potentials in overhead trolley and third-rail. Now that the improvements in direct-current motor construction, not only those promised but those actually accomplished, have made it possible, quite irrespective of what may be done with alternating-current motors, to use much higher potentials than ordinary—not of course as high as those available in single-phase alternating-current systems—the question sometimes arises: Will not the permissible potential be high enough, taking into account certain other facts, to meet in large measure the demands of railroad operation, whether by overhead or third-rail?

Engineers have generally proceeded on the assumption that the use of a sufficiently high potential for practical purposes is possible only with overhead conductors. In the Siemens-Schuckert installation at Mazières, (Fig. 30) where 2000 volts direct current are used, the current is taken from two trolley-wires of like potential supported by cross-wire catenaries from side poles of the same construction as is commonly used to carry the warning tickler.

Again, the third-wire system has been proposed, as on the Krizik road, and, on a recent installation with many grades and heavy tunnels in the Iselle mining district in France, where two overhead trolley-wires are used at 2400 volts, with the track as a neutral, and with the motors grouped in series of two, current being supplied by two Thury generators in series and grounded in the middle.

A comparison of potential relations giving the same losses on three systems is interesting. The systems are:

1. Three-wire, with 2 No. 0000 trolleys, and 75-lb. bonded single track.
2. Two-wire, with same trolley-wires and track-return.
3. Third rail, 70-lb. special, and with same track-return.

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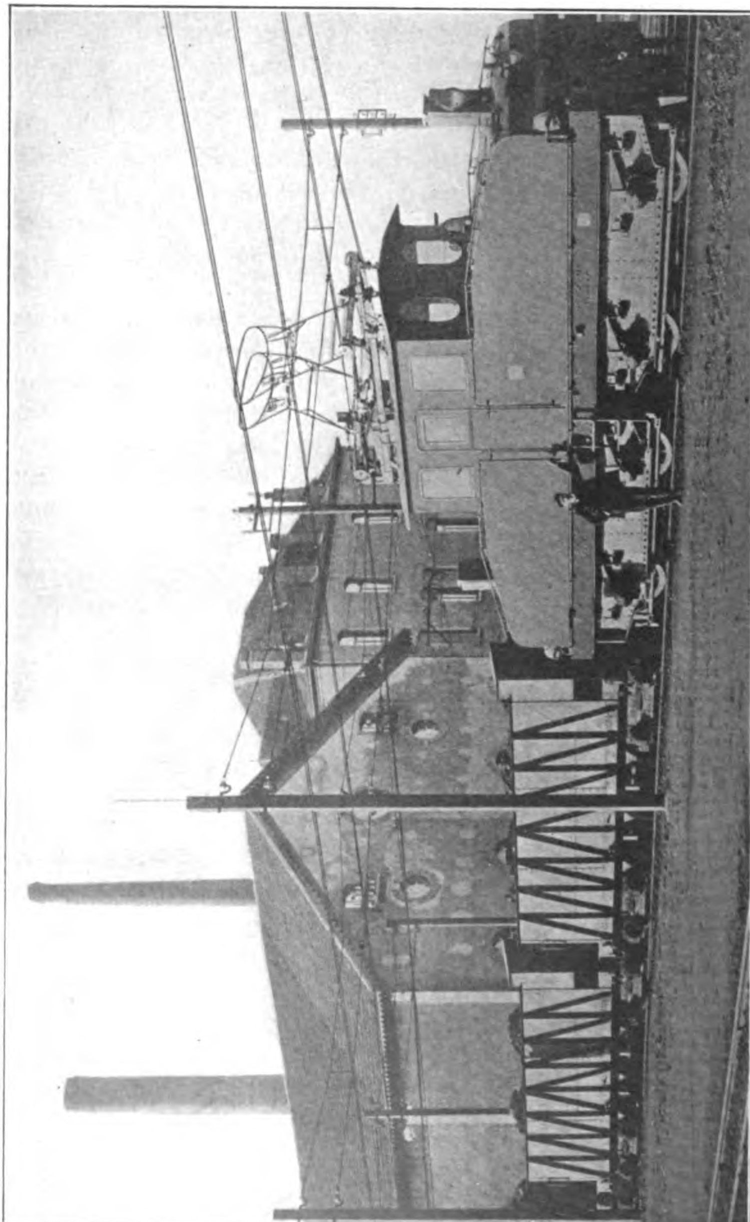

FIG. 30—Siemens-Schuckert 2000-volt direct-current installation at Mazières

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The following table gives the comparisons:

System	Resistance per double mile	Ratio of Resistance	$\sqrt{\text{Ratio}}$	Comparative Voltages	
No. 1	0.52 ohms	6.6667	2.58	2400	3100
No. 2	0.165 "	2.1154	1.45	1350	1740
No. 3	0.078 "	1.0000	1.00	930	1200

On such a showing there is little excuse for departing from the lower potentials and the simpler systems, and being handicapped with the higher voltage problems and complication of switches in the three-wire system. If any smaller trolley-wire be used, then the disparity between No. 1 or No. 2, and No. 3 would be emphasized.

The relation of potentials indicated in this table raises the question whether, in view of the disparity of current conducting capacity between an overhead system and the third-rail, it is not also possible that a sufficiently high potential can be used on the latter if from a practical railroad standpoint the balance of advantages and objections should be sufficiently in its favor to warrant its material extension.

Some time ago I stated that in my opinion it was practicable to operate at double the ordinary potentials with a properly protected under-contact sheathed third-rail. I am glad to be now able definitely to announce that it seems possible to construct and operate at these increased potentials with a degree of safety hitherto deemed doubtful. The details of the particular construction necessary must for practical reasons be withheld for the present.

Early alternating-current proposals. In all the discussion concerning direct-current and alternating-current systems, it should be kept in mind that the proposal to operate electric railways by single-phase alternating currents directly is not a novelty, but has had its ardent advocates for a good many years. The late Charles Van Derpoele was one of the earliest to propose this plan; Mr. Ward Leonard has for 15 years advocated the use of a single-phase trolley supplying a motor-generator to operate direct-current motors, a plan often now repeated; and Mr. Arnold attempted the solution by the combination of a single-phase motor operated in conjunction with a pneumatic engine. The Siemens & Halske company conducted the elaborate and costly

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high-speed Zossen experiments, and the Ganz company have been indefatigable workers in the polyphase field, their Valtellina and Simplon Tunnel installations deservedly commanding widespread attention. Finzi, Winter, Eichberg, La Tour, and others have developed the compensated repulsion type of single-phase motor, and committed themselves to its future. Lamme, Steinmetz, and our American manufacturers have essayed the solution with the compensated series type, at first with 25 cycles, and some now favoring 15 cycles or less.

It is, therefore, incorrect to say that the development is entirely a modern one while that of the direct-current motor has extended over a number of years, for that statement is misleading. Where a score of men were active in direct-current development in the earlier days, handicapped by lack of knowledge and experience, to-day the efforts of hundreds of highly trained men, with all the resources of great capital and manufacturing establishments, have been assiduously directed towards solving the single-phase problem. I think it is safe to say that there is little in its possibilities which has not for some time been fairly well known, and which could not be predicated very closely by theoretical investigation. Nor can I repress the feeling that the same amount of energy, money, and zeal spent on higher potential direct-current developments will produce some remarkable results.

Fifteen-cycle operation. The principal object sought, and certainly a most desirable one in the use of higher potentials, whether direct current or alternating current, is not now so much reduced cost of working conductors on a trunk-line system—for practice has shown that this cost is not materially affected—but lessened feeder investment, increase of substation distances, reduction of total sub-station capacity, and, in the single-phase system, the abolition of moving machinery in the sub-stations.

The raising of the potential on direct-current equipments will not be without some objections, not so much, as I have indicated, in the actual construction or use of the third-rail or the overhead trolley, nor because of difficulties in the matter of commutating and grounding, but rather on account of some reduction of capacity because of less slot and winding efficiency where the motors are individually constructed for the higher potentials, this feature being less important if two machines are

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operated in series. The controlling systems present some added difficulties, but nothing insuperable.

The degree of success of the alternating-current development will depend primarily on the development of capacity and all-round operative features in single-phase locomotive and car equipments. The 25-cycle motor (hitherto the only frequency actually installed for single-phase equipments) whether judged by individual comparison or specific equipments, as I have already illustrated, or the general testimony of electrical engineers of manufacturing companies has proved inadequate when compared with its rival. To correct this defect it has been proposed to adopt 15 cycles as a standard of operation.

This number of cycles has been under consideration for some time. It is successfully used by the Ganz company in its polyphase installations, it has been proposed in this country by the General Electric and Westinghouse companies for important work, and has lately been urged as a standard by a number of engineers.

Considered solely from the standpoint of the series commutator type of railway motor, a reduction from 25 to some lower compromise number of cycles—15 if you please—has certain distinct advantages; for it should make possible the use of higher field induction, larger air-gap, higher armature potential, slower armature speed, and less sparking—all making for increase of motor capacity for any given weight, and affording greater mechanical freedom in construction and operation. It likewise increases the capacity of trolley and track circuits, and raises the power-factor both of the line and the motor; but against this is an unavoidable increase in the weight of transformers, which, according to such facts as I have at hand, about offsets the saving in motor-weight, It appears, then, that the total weight of single-phase apparatus on a car for a given capacity is approximately the same within a very wide range of variation of the number of cycles. There are, in addition, special objections in the matter of turbine and generator construction, as well as in other directions.

It is difficult to establish exact comparison of equipment weights unless one personally conducts tests, or has complete technical reports which have been made on identical bases; but the following table is one comparison of early estimated weights of complete equipments of two recent typical types of like nominal capacity.

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Weight of 4-Motor Alternating-Current Equipments.

Motor	A	B
Cycles	15	25
Nominal capacity per motor	75 h.p.	75 h.p.
Individual Weights:		
Armature	1333 lb.	1146 lb.
Field	2414 "	2646 "
Gear, case, and pinion	398 "	407 "
Total Motor	4145 "	4199 "
Car Equipment:		
4 Motors	16580 lb.	16796 lb.
Transformer and rheostat	6750 "	4325 "
Controller and adjuncts	1000 "	1200 "
Trolley	500 "	500 "
Wiring, switches, etc. (?)	1950 "	1239 "
	26780 "	24060 "
Excess A over B	2720 "	

These totals are not final in either case, for the individual motor weights of each type will very likely be increased from 300 to 450 lbs. in regular manufacture. But allowing for such changes and corrections as seem reasonable, not only is no actual saving in *A* over *B* probable, but the excess of nearly a ton and a half against the 15 cycle equipment will remain in some makes. On the other hand, the manufacturers of *B* hope to show about 10% total saving in the weight of a 15 cycle equipment, but this hope is based upon theoretical estimates, not actual performance.

On other sizes it is probable that these relative differences will vary somewhat, but a comparison of the weight coefficients of large 15 cycle motors and direct current motors of like weight show a ratio of two to one in favor of the direct current machine.

Motor and locomotive constructions. Motors are of the geared and gearless types, may be entirely separate units or partly integral with the truck-frame, and may be wholly or partly spring-supported. Locomotive designs, influenced in part by the type of motor adopted, show a great variety of constructions, and may be very generally classed as rigid frame with all weight on the driving axles and without leading trucks; rigid frame with either single axle or bogie leading trucks at each end; and bogie-truck locomotives, the bogies being pivoted under the cab, and sometimes linked together.

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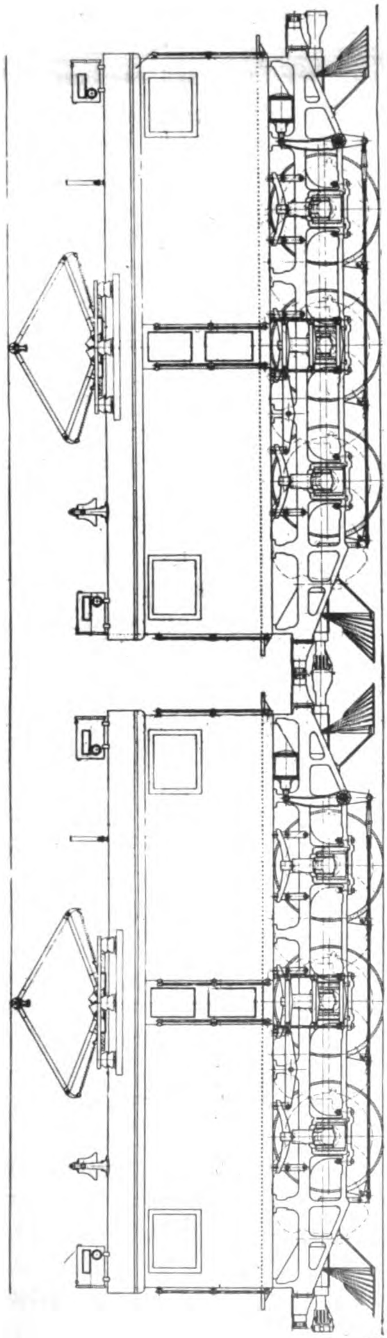

FIG. 31—1500 h.p. double-unit alternating-current locomotive—weight 140 tons.

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On all multiple-unit trains, except such as are designed for very high speed, in which case there is a possibility of a gearless-motor development, the standard method of motor-mounting introduced on the Manhattan Elevated Railway in 1886, and which has been in vogue ever since, bids fair to continue. It provides for centering the motor and carrying a part of its weight upon the driven axle, to which it is connected by any required ratio of gearing, the other end being flexibly suspended from the truck above the side springs.

Up to capacities of 250 h.p., about the limit required and permissible for motor-car equipment, single driving on one end can be used; but when this type of motor is built for larger sizes, in connection with locomotives, it seems almost necessary to provide for gear-driving at each end, which presents some difficulties in construction. To overcome these, the introduction of a spring has been proposed, but the use of an adjustable gear rim seems preferable.

To reduce the dead weight on the axle, one of the French railways some years ago centered the motor on a quill which surrounded, but was supported clear from the axle, connection being made from the quills to the drivers through springs.

The rigid wheel-base type of locomotive without leading trucks is illustrated by an direct-current machine built under the direction of some associates and myself a number of years ago for experimental work on one of the lines running out of Chicago, and also by one class of double-unit locomotives which has been frequently proposed by various companies for single-phase alternating-current operation.

The former, (Fig. 3) of 1,000 h.p. capacity, had four axles, on each of which was mounted the armature of a gearless motor, the field-magnets being attached to the axle-boxes. To insure equal duty on motors, and the maximum tractive effort for its 70 tons of weight, the drivers were coupled together and quarter-cranked, the connecting rods being balanced. The controller was operated by an air cylinder, and followed in time and degree the motion of a pilot lever.

Each half of the double-unit locomotive shown (Fig. 31) has three axles, to each of which is geared an alternating-current motor, after the usual fashion. Each section has a rigid wheel-base of about 12.5 ft., and weighs from 65 to 70 tons, making a total weight of from 130 to 140 tons for a unit having a rated capacity of about 1500 h.p. with natural ventilation.

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An analysis of the action of a locomotive demonstrates beyond question that this general type of machine, that is, one having a rigid frame and no guiding trucks, is limited to moderate speeds, and would be unsafe if operated at high speed on a road with much curvature and special work. Notwithstanding the fact that it has been strenuously advocated, even recently, I think this particular type will not find favor among the railroad men, and it is already practically abandoned in the proposals of the manufacturers, in favor of a bogie-truck type, or an articulated type composed of two rigid frames with single axle leading trucks at each end of the complete unit. It is also proposed to carry the geared motors, centered on a spring-connected quill, directly over the main driving-axles, and to support the entire motor by springs from the locomotive-frame.

Particular interest naturally centers upon the distinctive types of locomotives installed on four important railway systems, the Valtellina and the Simplon Tunnel in Switzerland, the NewYork Central, and the New York and New Haven, which well illustrate three of the principal methods of construction developed to meet the demands of different electrical systems. I will briefly describe each, as well as make some comment upon a few of the many other types recently proposed.

As illustrating a high order of electrical and mechanical engineering, the work of the Ganz Company merits special mention; for it is undoubtedly true that the present status of the polyphase system, which stands on a favored plane with many Italian engineers, is owing almost entirely to the efforts of this company.

The polyphase motor locomotives (Fig. 6) built for the Valtellina Railway and for the Simplon Tunnel are strikingly individual in their construction. The axle mounting of motors is abandoned, the motors being entirely separate units mounted on the locomotive frame, and coupled to each other and the 62-inch driving wheels through an ingenious combination of connecting- and side-rods. Of the three pairs of main drivers, the middle only is journaled in the main frame, each end-pair being journaled at one end of a pivoted guiding truck, at the outer end of which are guiding wheels about one half the diameter of the driving wheels. The end drivers have a limited end play, and one king bolt has a similar freedom of movement, while the other is fixed, resulting altogether in great freedom of adjustment to track curvature. The two motors, spring-supported through the locomotive

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frame, are each quarter-cranked, and connected to side-rods having downwardly projecting jaws which loosely engage the driving pins of the middle drivers, the centers of which are somewhat below the centers of the motors. On each side of the jaws of the side-rod are coupled the connecting-rods of the outer drivers, provision being made in all bearings for the necessary freedom of movement and adjustment.

In an earlier type, the locomotives were equipped with two sets of twin motors for high and low tension, the low tension to be operated in cascade relation to get slow speed in starting and for running on grades, then to be cut out and the regular running to be with the high-tension motors alone. In the latest machines the twin-motor construction has been abandoned, and the locomotives are equipped with two 15-cycle high-tension polyphase motors, one having 8 and the other 12 poles, and an arrangement of field-circuits in the latter machine such that it can be temporarily made a low-tension motor operating in cascade relation with the other. This combination permits of three regular operating speeds of about 16, 26, and 40 miles per hour. At the lowest speed the motors are in cascade relation with high draw-bar pull, at middle speed the 12-pole motor is in operation alone on high tension, and at the highest speed the 8 pole motor is used alone, likewise on high tension. Of course the physical connection of the two motors together and to all drivers makes this method of operation possible. The rated capacity of the motors, as given by Valatin, is extraordinarily high, that with the 12 poles being stated as 1200 h.p. and that with 8 poles 1500 h.p., based upon the one hour rise of temperature to 75 degrees. The motors average about 13 tons each.

The use of connecting-rods in this locomotive is not as objectionable as the use of the driving- and connecting-rods in a steam locomotive, because the strains are very different and the rotative weights can be far more perfectly balanced. It can be fairly said to have the advantage that with the minimum possible weight of locomotive there is no such thing as slipping an individual wheel, a trouble which will occur at times with all locomotives having independently driven axles if equipped with powerful enough motors, because of variation in motor characteristics, track and wheel conditions, and unequal wheel pressure caused by the drawbar pull.

Almost the entire weight of the locomotive is spring-borne, and the behavior of the machine on curves even at high speeds

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ought to be very satisfactory. The same general construction would lend itself very effectively to the application of high-tension inter-pole direct-current motors, and may be very seriously considered in this connection.

The general characteristics of the New York Central type of locomotive (Fig. 4) the Batchelor machine as developed by the General Electric Company, is pretty generally understood, and my description will be limited. It consists essentially of a heavy steel frame in which are journaled four main axles, and which is terminated by pivoted single-axle ponies provided with spring resistance against deflection from the central position. The

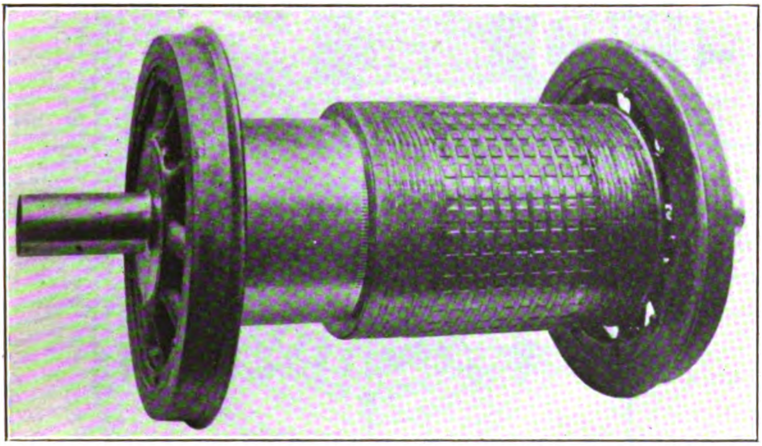

FIG. 32—Armature of bipolar direct-current motor

motors are the gearless type, the armatures being mounted directly on the axles, (Fig. 32) and the bi-polar field-magnets forming an integral part of the main frame; they are, therefore, carried with it by the equalizing springs, and have free motion relative to the armatures. In addition to the regular truck frame, an additional path is provided for the magnetic flux, which passes through all the armatures and field poles in series, by a heavy bar extending the length of the frame and carried above the motors.

Being of the two-pole type, (Fig. 33) and with a quadrant winding, the motors are extraordinarily free from sparking tendencies; in fact, they are, structurally, natural 1200-volt machines, although only wound for present operation at 750. So marked is

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this characteristic, that the brushes, which are 180 degrees apart, instead of being carried on yokes concentrically with the commutator, are carried on arms attached to the field-magnet frame, (Fig. 34) and although moving with it function perfectly.

The electrical and mechanical construction is, therefore, reduced to an acme of simplicity never hitherto attained in electric locomotives, for not only are there no gears, but there are no armature or field bearings, quills, driving-spiders, or special

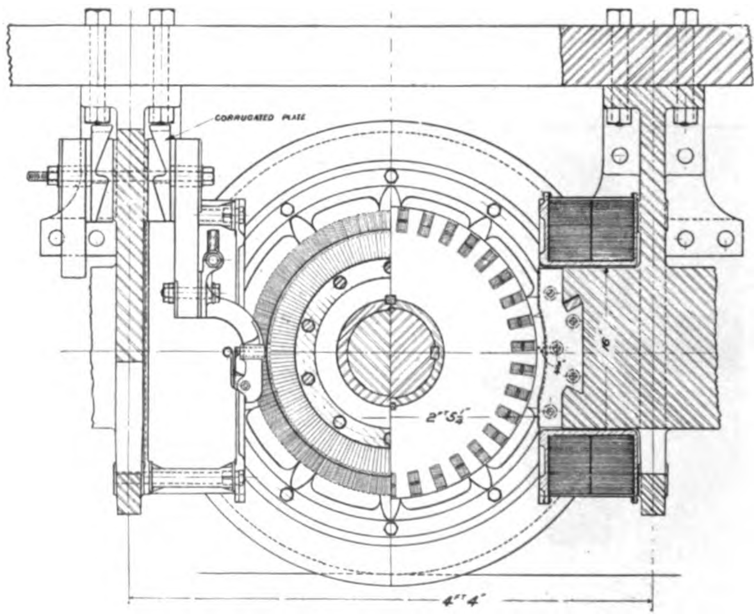

FIG. 33 - Longitudinal section--bipolar direct-current motor.

spring connections, although all the weight of the motors except the armature is spring supported.

The air-gap is very large, and as the pole pieces are very nearly flat a complete axle unit with its armature can be readily dropped out, and replaced without disturbing the balance of the motor equipment. This type of machine, of course, cannot be used with any form of alternating current directly, no matter what the frequency.

When first proposed the design was considered so radical that its choice met with a good deal of criticism, but experimental trials extending over two years, with 67,000 miles of operation,

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amply demonstrated its remarkable reliability and efficiency, qualities confirmed by the operation of 35 of these locomotives now delivered and in regular service.

The total weight of the locomotive, without heating equipment, is about 95 tons, of which 70 tons is on the drivers. The nominal capacity, with 75 degrees rise and natural ventilation, is 2200 h.p., at which output with 600 volts the machines run at 300 revolutions, corresponding to 40 miles an hour. The rigid wheel-base is 13 feet, the total wheel-base 27 feet, and the length over all 37 feet.

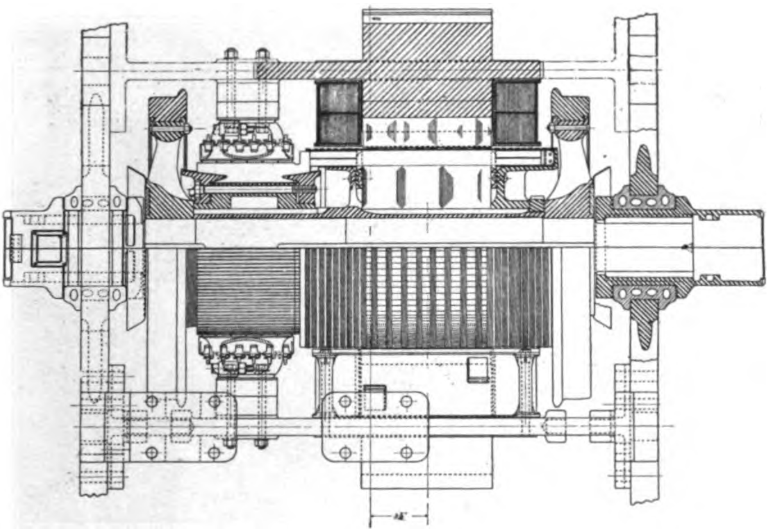

FIG. 34—Transverse section—bipolar direct-current motor

The individual control is the series-parallel bridge method, with resistance variation, the grouping of motors varying from four in series to four in multiple, and current is taken from the under-contact rail by side-extending flipper-shoes.

The original specifications required each locomotive to handle a trailing load of 400 tons on a specified service, two locomotives, under common control by the multiple-unit system, to be used with the heaviest trains on high-speed runs. It is most satisfactory to find that these locomotives have developed an extraordinary emergency hauling capacity, such that there is

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no train pulled out of the Grand Central Station, into which the first run was made September 30, 1906, which cannot be handled by a single machine at the speeds required within the limits of present operation.

The exigencies of service are responsible for a recent remarkable test of this tractive power. On April 26, the Lake Shore Limited, north bound, consisting of nine heavy Pullman cars hauled by a Central-Atlantic type of steam locomotive, was stopped in the tunnel under 66th street, on a point 0.5% upgrade, because of some mishap to the engine. Following it was a train of seven standard day coaches, shopbound and hauled

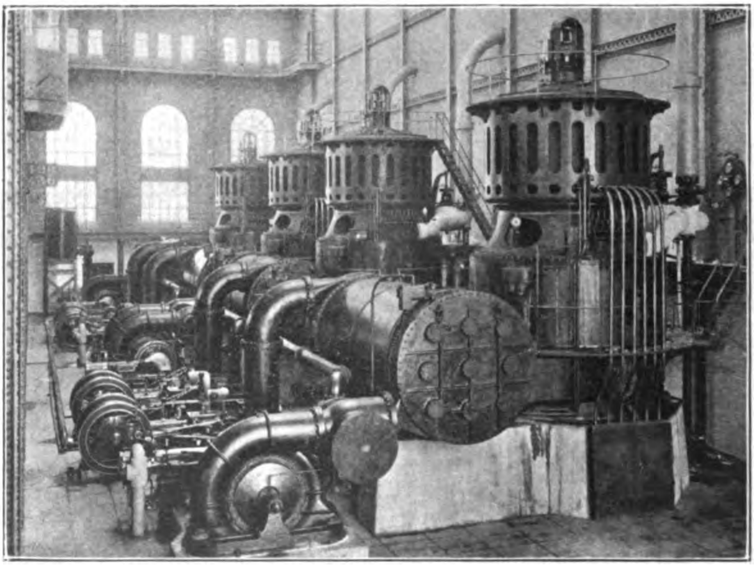

FIG. 35 – Turbine room, Port Morris power station

by an electric locomotive, which promptly coupled on to the leading train, and without any assistance from the steam locomotive, which was dead, started the entire load of 16 cars and 2 locomotives, weighing nearly 1,000 tons, with good acceleration, and made the run up a 1.02% grade, a half-mile long, at satisfactory speed and without difficulty.

Those concerned with the planning and installing of the New York Central equipment justly feel that it is epoch-making in forwarding the march of electrification, and it is gratifying to note that although the electric service was inaugurated only as

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recently as the 22nd of last December, has been developed under extraordinarily difficult circumstances, and has had to face much adverse criticism because of a serious accident due to extraneous causes, already 305 train movements, representing 86% of the present total of the New York Central and Harlem trains, both locomotive-drawn and multiple-unit, are operated electrically. The aggregate delay has been less than with the old steam service, a fact particularly noticeable in times of snow-storms. The main station (Fig. 35) output for 24 hours is but about 65,000 kilowatt-hours, and when the batteries are in service but one steam unit is required at time of maximum load.

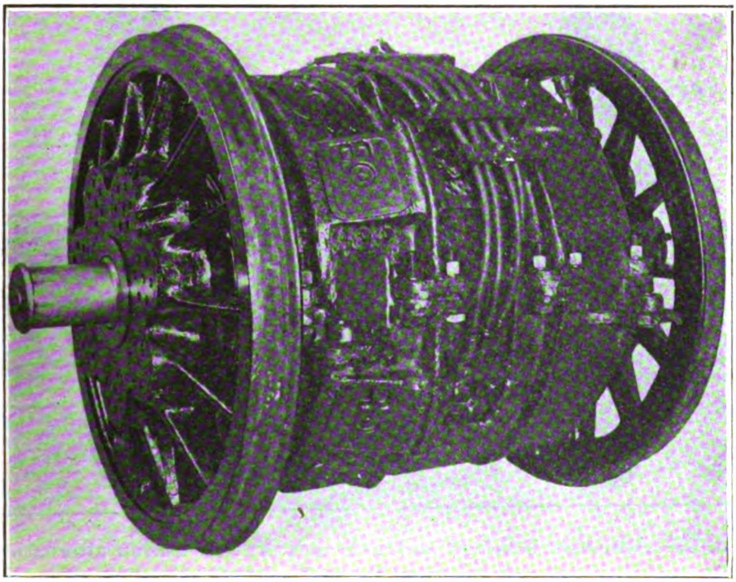

FIG. 36—Motor and axle unit of alternating-current New Haven locomotive

The New Haven alternating current-direct current locomotive, built by the Westinghouse Electric & Manufacturing Company, is of the 2-axle free bogie type, the bogies being pivoted under, and transmitting their effort through the frame which carries the cab, in which are mounted the transformers, blowers' rheostats, and controllers (Fig. 37). On each truck are mounted two spring-supported motors, each complete within itself. The armatures are carried on quills, terminating in spiders at each end, which engage eccentrically wound springs enclosed in pockets in the main drivers (Figs. 36-39).

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The rigid wheel-base is 8 feet, the total wheel-base 22 feet, and the length over all 37 feet. The weight of the locomotive is 93 tons, having been raised considerably over early expectations. It has an hour rating, on the usual standard, of 1,000 h.p. when operated at 25 cycles, but is equipped with blowers to raise the average capacity. It is intended to handle a 200-ton trailing load at schedule, with some margin of performance.

Although built primarily for operating directly from 11,000-volt single-phase alternating current, these locomotives must

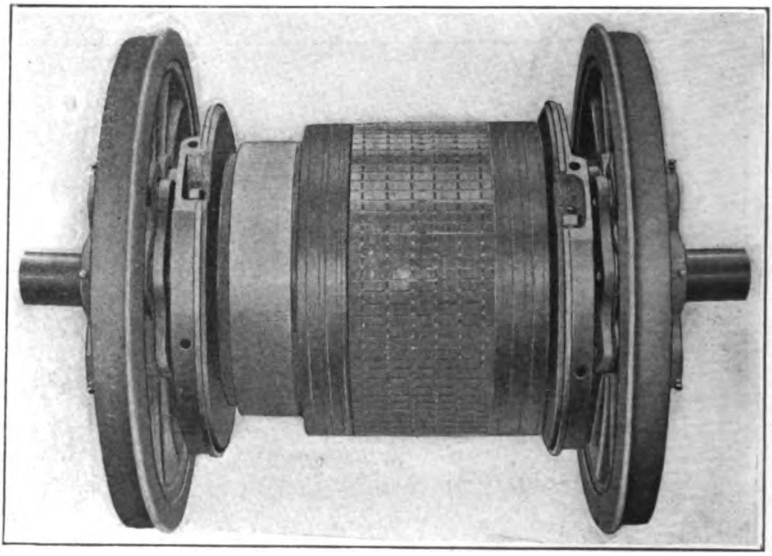

FIG. 37—Armature bearings and axle unit of New Haven alternating-current locomotive

operate also from the 650-volt direct current while on the Harlem tracks. They, therefore, have additional control provision, and besides the double-pantograph collectors, have contact shoes, those on the side being arranged for lifting by air pressure on account of limited clearances on a part of the run.

The motor armatures are wound for operation at a normal maximum of about 250 volts, and hence are connected in permanent series of two, while the field-circuits are arranged for each pair of motors in a separate group, and for series-parallel grouping independently of the armature circuits, to provide for the varying flux in alternating-current and direct-current operation. Of

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course the two motor groups can be connected for series-parallel operation with direct-current supply, but with the disadvantage of using about double the amount of current at slow speeds that is required when four motors, each wound for the full potential, are in series.

The first of these machines, pulling a short train, made entry into the Grand Central Station on May 11, 1907, and in a short time the operation of equipment should be under service test.

Some question has been raised as to whether trucks with drivers of so large a diameter, 62 inches, on which are concentrated 15 tons of motors in a limited wheel-base, will track properly under all conditions of rail. Experience, however, is the final criterion.

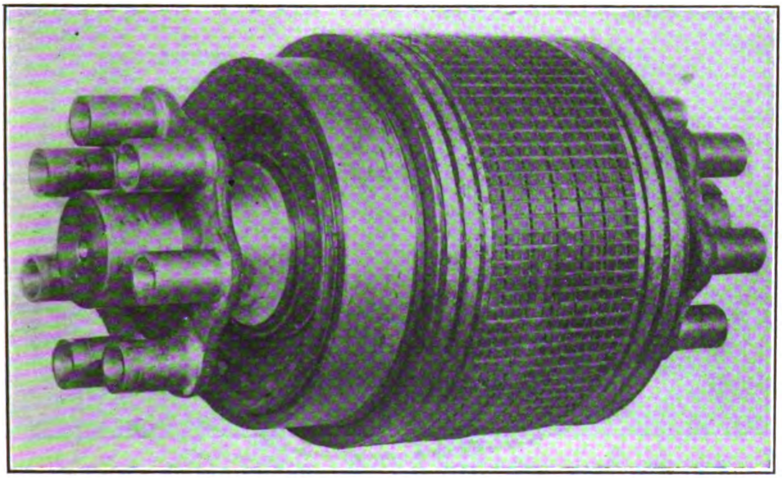

FIG. 38—Armature and driving spider of New Haven alternating-current locomotive.

In order to combine the possibility of single-phase alternating-current current transmission at high voltage by overhead trolley and the unquestioned advantages of the direct-current motor, it has several times been proposed to introduce between the line supply and the motors a motor-generator set, comprising an induction motor taking current directly from the line, and driving a continuous-current generator to supply the motors, this converting set being carried in the main cab, with provision made for the extra weight by bogie trucks at each end, (Fig. 41) or in an independent tender taking the place of the steam tender in existing steam practice (Fig. 40). Of course this is the introduction

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of a moving sub-station individual to the locomotive which is operated by it, and makes the latter subject to all the idiosyncrasies of the intermediate apparatus, besides laying up an enormously expensive machine in case of any special trouble. Where the motor-generator set is carried in a separate tender, this disablement only cuts out a part of the equipment, which can be replaced by another like part, but in any case it is debatable whether such a moving sub-station offers any advantage over the stationary one.

Sometime since I made a very careful investigation of the possibilities of direct-current gearless and geared motors, (Figs. 42-43) the former of the bi-polar type, for identically the same service, a very severe one.

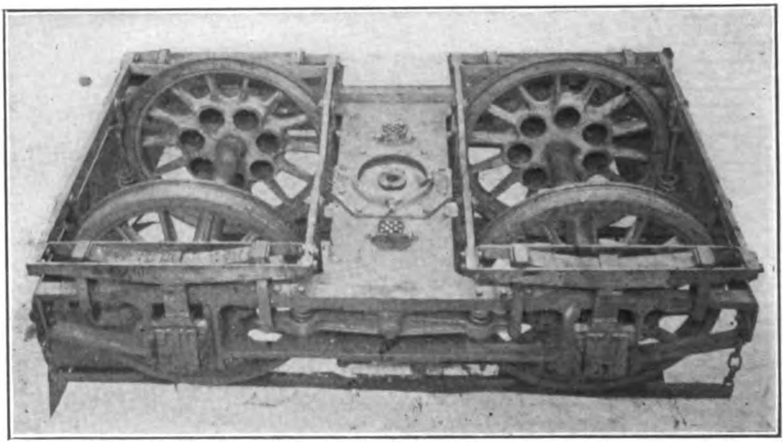

FIG. 39—Truck of New Haven alternating-current locomotive.

Both machines are of the four-axle bogie-truck type, the trucks being linked together. The geared locomotive weighs 93 tons and the gearless 126 tons, but the weight per axle is well within the usual allowance. On each truck are four motors, connected two in series, to be operated at a maximum line potential of 1500 volts. The geared motor construction is of the usual standard, but fitted with commutating poles, while the gearless machine has modified bi-polar motors of the N. Y. Central type.

A comparison of the efficiency curves of the two machines is interesting, these showing for each from 87 to 88% on a five-hour load, and falling only to 83% with 50% increase, while at

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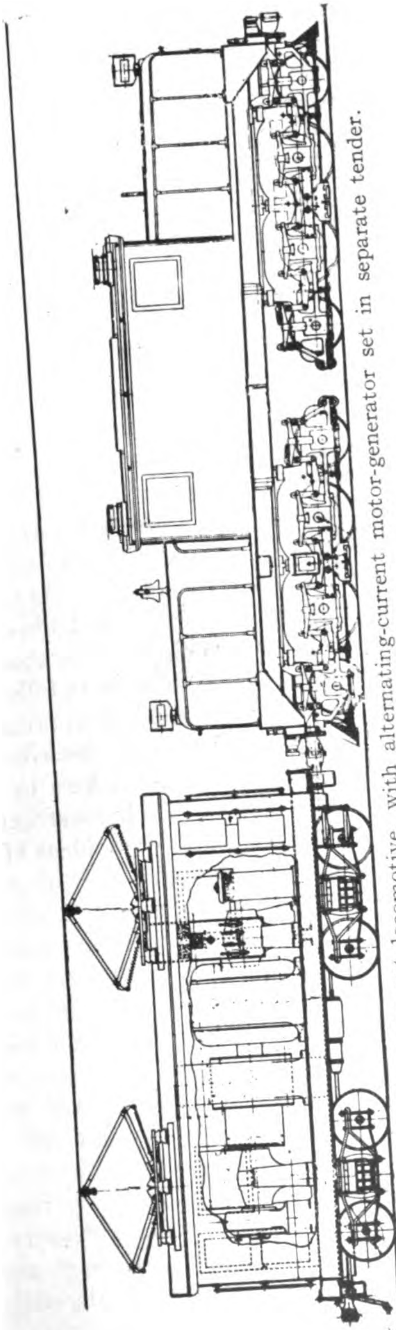

FIG. 40—Direct-current locomotive, with alternating-current motor-generator set in separate tender.

half this load the efficiency of the gearless machine is much higher than that of the geared. Some adequate idea of the capacity of the gearless machine may be gathered from a statement that it will maintain a drawbar pull of nearly 25,000 lb. at a good rate of speed for several hours continuously, and with natural ventilation. These extraordinary characteristics would, for the class of service for which these machines were considered, amply warrant the additional weight because of the simplicity of the gearless machine.

A very promising type of machine, (Fig. 44) embodying many of the good features of those which had preceded it, is now under construction by the General Electric Company, for use either on direct current, or with a motor-generator set supplied from an alternating-current trolley. This machine is of the 4-axle free bogie type, the drawbar pull being taken through the main frame. On each truck, and forming an integral part with it, are two bipolar gearless motors driving the middle pair of axles, and at either end of each truck is a pair of leading wheels of smaller diameter, which have a limited, spring-resisted side play. The normal wheel-base of each truck is 12 feet, the total wheel-base 32 feet, and the length over all 36 feet. This machine should be capable of an almost unmatched speed and freedom in following irregular curvatures, and with special ease of track approach.

The various locomotives thus briefly described are but a fraction of those proposed by various makers to fit particular conditions and types of apparatus. Their construction does not, in many particulars, meet the preconceived ideas of some steam-locomotive builders, with whom a high center of gravity and all the weight possible carried on springs is a cardinal principle, and a very correct one when we consider the necessities of the steam locomotive. The electric locomotive has a lower center of gravity, that of the New York Central machine being about 44 inches, the New Haven 51, and the Ganz probably somewhat higher, while that of the steam locomotive is sometimes as high as 73 inches. The electric machine, therefore, will have less tendency to topple over, but a greater resultant side pressure in case of irregularity of track when entering a curve, or running on an irregular track, than its rival, a larger portion of whose weight heels over and increases the vertical pressure on the rail. Careful investigation, however, carried on through many sources, and inaugurated by reason of the recent derailment on the New York Central road, seems to indicate that with electric

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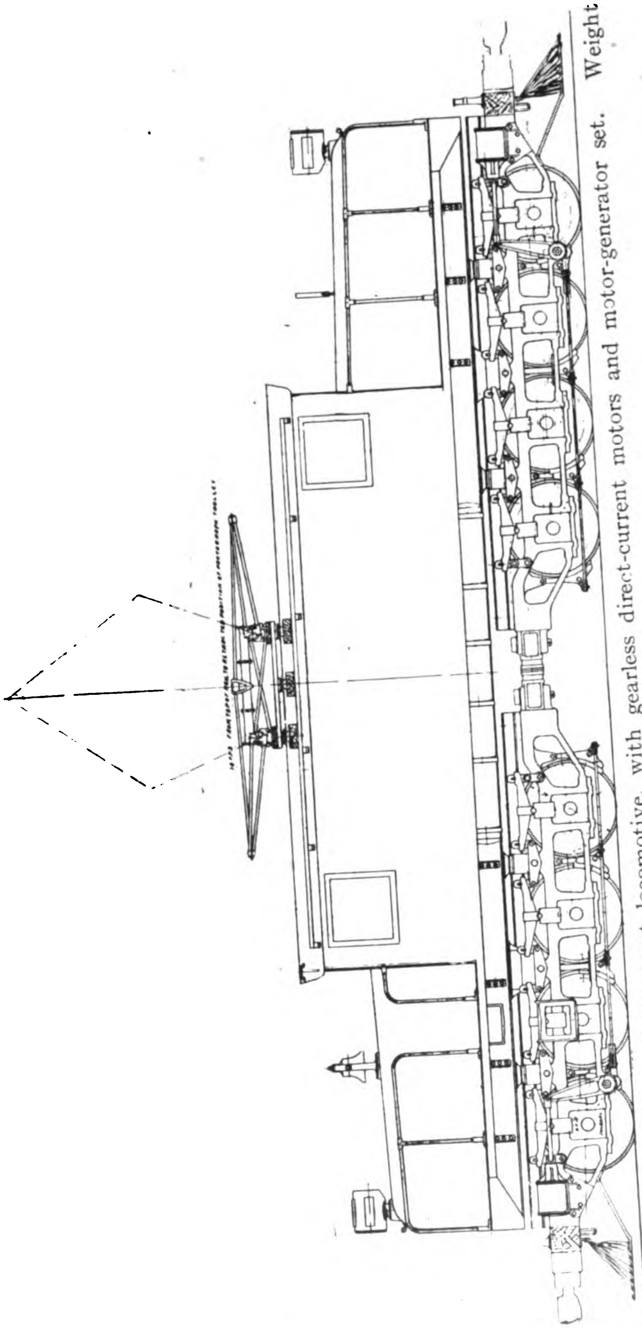

FIG. 41—1500-h.p. alternating-current locomotive, with gearless direct-current motors and motor-generator set. Weight about 160 tons.

motors properly guided any increased tendency to side-thrust is more than compensated for by certain other advantages

Train Control and Operation. Restriction of operation in an electric system to methods in vogue with steam operation would be a useless throwing away of one of the geatest possibilities of improvement in train operation where passenger service is heavy and terminal facilities congested. Ten years ago I inaugurated on the South Side Elevated of Chicago a new system of train control which permitted the aggregation into trains of any number of independently equipped motor cars, and dead cars if desired, and their control from either end of any car, irrespective of train make-up. This system, now known the world over as the "multiple-unit," (Fig. 45) has made such advance that it is now generally recognized and adopted as the best method of handling trains wherever service is crowded and high schedules are required.

The essential result accomplished by this system is increase of capacity, by providing high power equipments proportional to the length of the train, increased schedules and density of train movement, the lowest maximum speeds for any given schedule similarity of equipment, reduced switching and signal movements, increased safety, and generally the utmost independence and facility of operation. Whatever tentative plans may for the present be adopted, I believe that it is inevitable that all local and suburban passenger service on electrically equipped railways requiring train operation will be eventually conducted on the multiple-unit plan, and its use will spread over a continually increasing area, even to the operation of passenger cars run over divisions of considerable length.

But it must be borne in mind that we are dealing all the while with necessarily increased weights of considerable amount, because of the use of steel car-bodies, heavier trucks, and addition of motor equipment which must provide the power to propel itself as well as the cars. Increase of schedule also demands increased capacity of motors, and it is, therefore, of the utmost importance that capacity be got with a minimum of weight, and likewise with restricted armature speeds, which, where stops are frequent, add materially to the "virtual" weight of the car; because not only does the weight of the armatures have to be accelerated and carried in a linear direction with the inert parts of the car, but they must have energy stored in them because of their rotation, a considerable part of which is thrown away in braking. According to all present

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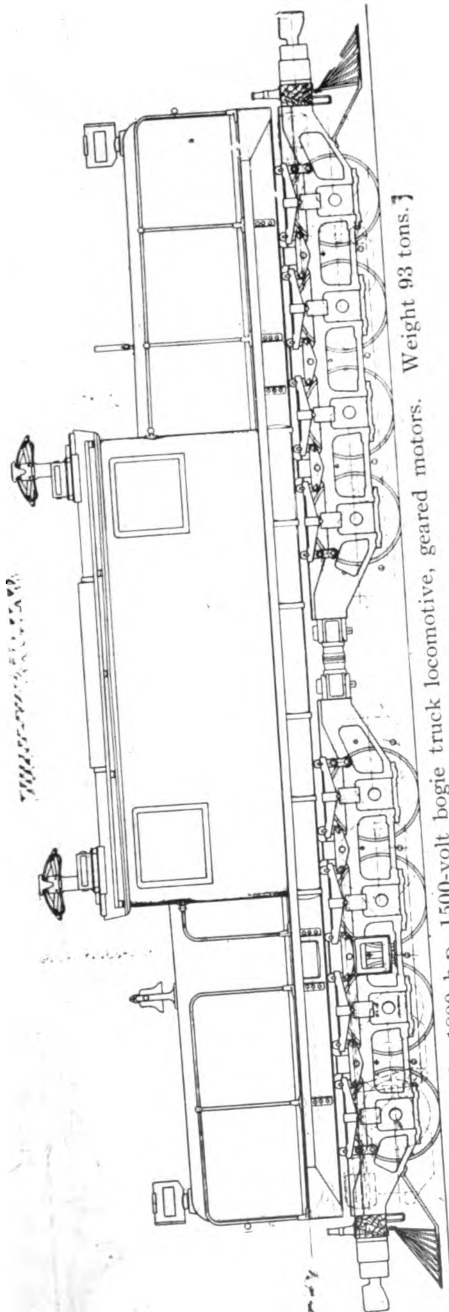

FIG. 42—1800 h.p., 1500-volt bogie truck locomotive, geared motors. Weight 93 tons.]

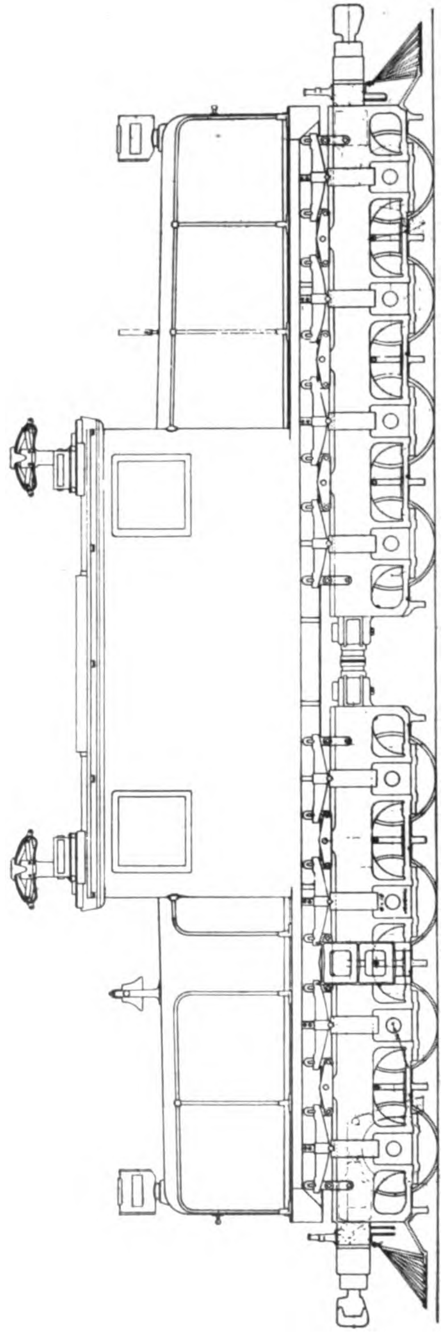

FIG. 43—1800 h.p., 1500-volt bogie truck locomotive, gearless motors Weight, 126 tons.

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developments, as I have already indicated, the direct-current equipment has in this service an enormous advantage over any single-phase alternating-current motor equipment with its car transformer.

Irrespective of the benefits to passengers, and the influence in building up suburban service by providing a high schedule train system which can be absolutely adjusted to the needs of traffic, the influence on the capacity of the terminal facilities of a railway is of the utmost importance. It has been declared by a competent English authority that the use of multiple-unit trains in the suburban service of a congested station at least doubles the capacity of that station in the matter of track movements and the dispatch of trains, not only on account of the ability to operate the trains from any point and in any length, but also because of halving the number of switch and signal movements necessary where locomotives are used. In addition, the electric locomotives necessary on through trains, being double-ended, compact for their capacity, and needing no turn-tables, occupy much less track and yard space than steam machines. Again, the use of electricity makes it possible to double-deck a terminal, bringing through trains in on one level and suburban trains on another, and using both for storage. As a net result, it may be safely stated that so far as train movements are concerned, the capacity of a yard, over and above that required for the storage of cars alone, can be trebled as compared with steam-locomotive-drawn trains. In addition, the yards can be roofed over, and the space utilized for streets, parks, or buildings.

The remarkable extension of the multiple-unit system, and its recent application to locomotive practice, as for example on the New York Central Railroad, has led to the suggestion that freight trains shall be equipped with secondary controlling lines, and that a plurality of locomotives, not only at the head of the trains but distributed throughout it, shall be handled by a single operator on the leading engine, whose controller shall be provided with the automatic safeguards common to the service which has already been developed. I do not hesitate to pronounce this an impracticable scheme for general application. Quite aside from the cost of equipping the hundreds of thousands of rapidly deteriorating freight cars, the majority of whose train lines would not be used, it would be against public policy, and contrary to the most ordinary safety of train operation, to leave such an extended and high-powered train in charge of a single man.

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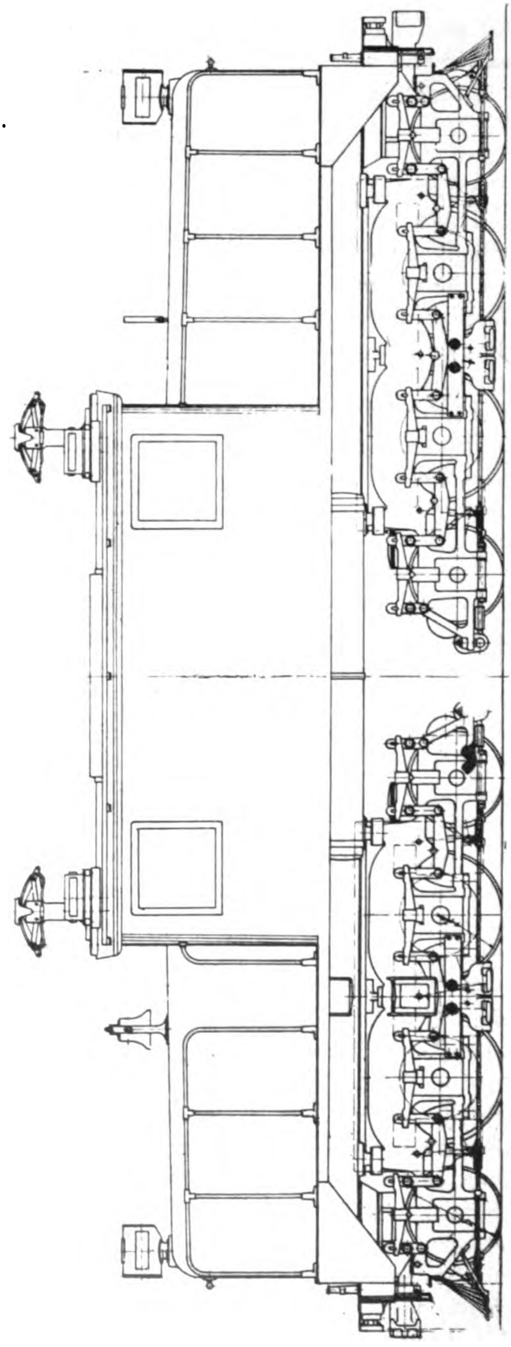

FIG. 44—High-speed bogie truck direct-current locomotive, gearless motors Weight 80 to 110 tons.

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Locomotive operation is distinctly different to that on elevated and underground roads, and the operators make their runs under widely varying conditions. The handling of a long freight train is entirely unlike that of a train made up principally of motor cars; it has to be coaxed, favored, and nursed, for scarcely any two starts are alike. As useful as automatic controller advance is with the ordinary multiple-unit train, and even admitting, which is debatable, the advisability of connecting up the air-brake with the control, it is safe to say that in ordinary freight operation these features should not be added to the controller, and if they were the engineer in time would beat them.

While double-headers under a common control will undoubtedly be used when necessary on both freight and passenger trains, when one considers all the varying conditions of trunk-line operation, neither public policy, safe railroad operation, nor if you please, labor conditions, would permit the handling of a train with two or more locomotives so coupled up, with only one man in the cab. It should not be permitted even with a single locomotive, and I do not believe that any man who has had practical experience in riding locomotives would long continue to adhere to any such proposal.

Storage-batteries. The use of the storage-battery in connection with electric railway operation is a proposal concerning which much may be said, for and against, depending largely upon what value one attaches to restriction of peak-loads on moving machinery and to insurance. That it has been, and is being used successfully in connection with direct-current equipment of moderate potential admits of no dispute, and it has been stated that it is equally available for alternating-current installations. This latter claim is misleading. On direct-current systems the principal function of a battery is that of an equalizer. If installed at a central or sub-station it is usual to provide boosters to govern the charging and discharging. These, however, are only of differential watt capacity, and while they are necessary for regulation, it is perfectly possible to use the battery in some emergencies by direct connection with the line. Sometimes the battery is used at an auxiliary sub-station without any boosters whatever, the charging and discharging being determined by the drop on the line, or by the use of an extra feeder.

With an alternating-current system the battery at a sub-station plays an entirely different role. It must be charged by a

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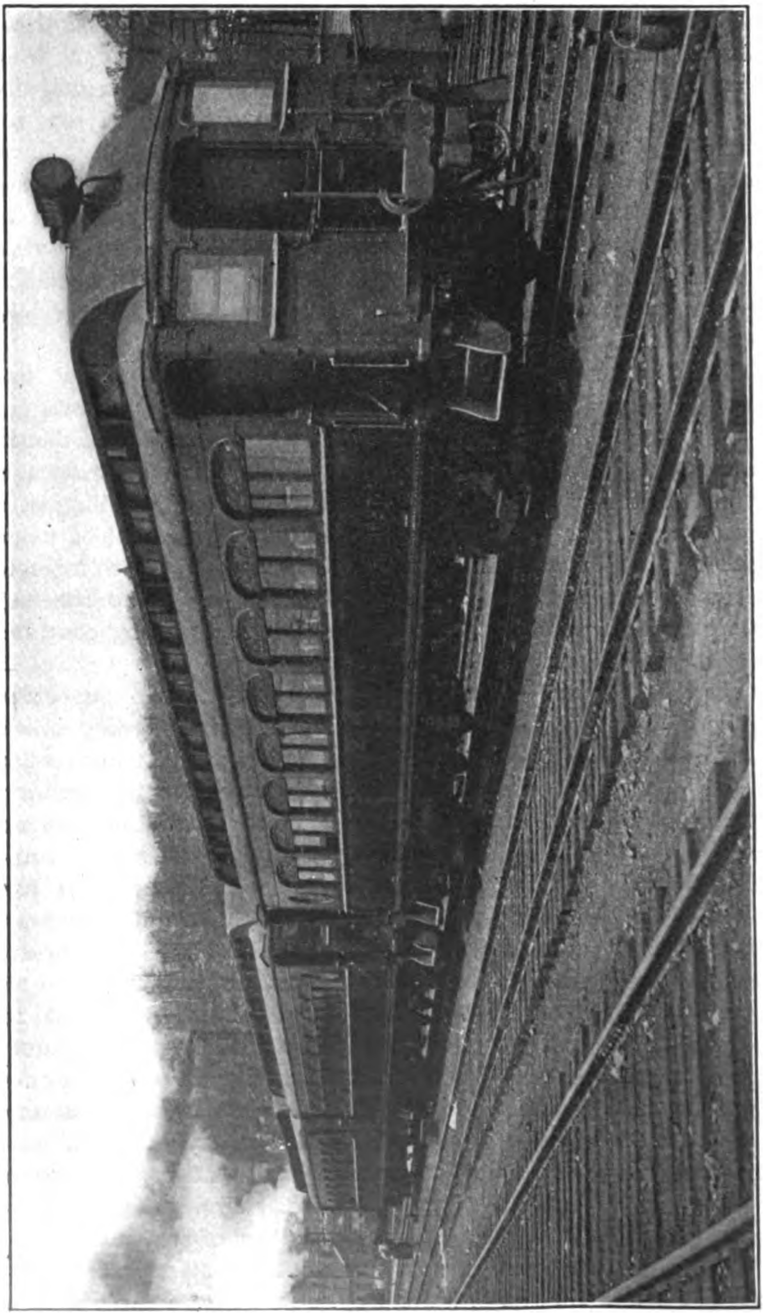

FIG. 45—New York Central multiple-unit train.

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direct-current generator driven by an alternating-current motor, and in discharging drives the alternating-current motor as a dynamo through the direct-current generator acting as a motor. In addition to the introduction of moving machinery in an alternating-current sub-station, its watt capacity must be equal to that of the full discharge of the battery, and the latter can have no function in supplying current to the working conductor except through the medium of two rotating machines of large capacity.

Where current is purchased from a water-power plant, and it is necessary to change frequency as well as restrict the peak-load by which charge for power may be regulated, the battery may be used in combination with an alternating-current motor, a single-phase generator and a direct-current machine; the alternating-current motor driving the single-phase generator and the direct-current machine to charge the battery when the load on the line is light, and the alternating-current motor and the direct-current machine, operating as a motor supplied by current from the battery, together driving the generator when the load is heavy.

Use of step-up and step-down transformers. Where the distance is not great, as on the present proposed limited operation of the New Haven road, both step-up and step-down transformers have been omitted, and the 11,000-volt trolley-line is supplied from the station switchboard. This means direct connection between an extended system of overhead working conductors and generators operated at high potential, with one side grounded, with, of course, whatever protection lightning-arresters can provide. Such are the vagaries of lightning and the uncertainty of the very best arresters, that I cannot but feel that this practice, which subjects costly generating equipments to direct lightning attack and special grounding stress, will not obtain to any great extent; for the possibility of laying up a complete unit of great capacity, steam engine as well as generator, because of a lightning flash or accidental ground, is too great a penalty to pay for eliminating transformers, and is a special handicap upon the possibilities of transmission.

It is certain that standardization should be directed to the construction of generators. Any material increase of potential above that now common means reduced capacity and efficiency, increased danger of breakdown, and greatly increases individual cost, to say nothing of the capitalized risk of failure. Quite aside from the question of cost and efficiency, air cooling, the

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only possible method for generators, manifestly cannot be safely carried above that which is tolerable for static transformers, which, when wound for the higher potentials, are invariably oil-cooled. Therefore I expect to see standardization of generator potentials, the pressure being stepped up by transformers to whatever transmission potential is necessary, and then stepped down to the working pressure on the trolley-wire if alternating current be used, or to a lower pressure and converted if direct current be used.

The transformer, *per se*, is the simplest and most flexible device for changing alternating-current volume and pressure, and its moderate cost and high efficiency, taken in connection with the like elements of moderately high potential generators, will leave the total cost and efficiency of generating equipment roughly the same. There will be the added very great practical advantage that the generators not only work at lower potentials, but on closed metallic circuits, are removed from direct contact with working conductors and earth; and have interposed between them and the line at least one set of static transformers, which practical experience has shown to be one of the best generator safeguards against lightning, and which, if broken down do not involve large and costly units, nor wholesale sacrifice of capacity.

General cost comparison of direct-current and single-phase alternating-current systems. Summarizing briefly, the alternating-current—direct-current and the single-phase alternating-current systems have certain features in common, and others differing, which may be briefly stated as follows:

Each must have a central station, which in the former will generate three-phase currents delivered to step-up transformers to raise the voltage of the transmission lines to any required degree, while in the latter, single-phase currents will be generated at a practical potential, and likewise stepped-up for transmission. Assuming equal kilowatt outputs, the generating part of the three-phase system will be cheaper than that of the single-phase, because of the higher weight-efficiency of the polyphase apparatus; but the switching devices will be somewhat more costly, while the transformers will cost about the same, with the net result that the cost of installation per kilowatt, and with equal conditions in the matter of speed, reliability, and efficiency, will be somewhat less for the polyphase than for the single-phase equipment.

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The transmission lines, especially where provision is made for duplicate or reserve circuits, may for the purpose of this general comparison be roughly considered as of equal cost.

Sub-station transformers must be provided on each system to lower the transmission to the operating or transforming voltages. There will be approximately an equality in these features.

Just here is a line of departure, the transformed current in the alternating-current—direct-current system being passed through synchronous converters, and delivered to either an overhead trolley or a third-rail, assuming for this purpose the latter, while in the single-phase system it is delivered to an overhead trolley. The converters and the necessary housing and switching apparatus is an excess cost chargeable to the older system.

We come now to the working conductors of the two systems. The third-rail, which is prohibitive to the alternating-current system, cannot be put in except on what may be fairly called a permanent basis, at a certain approximate cost per mile of track equipped. The overhead trolley for the alternating-current system can be put in on either of two plans, one more or less tentative and temporary, using wooden poles and wire suspensions; the other, which is practically the only way affording reasonable permanence, with steel poles or bridge supports. Under this latter condition of permanence, the cost of such an overhead system per mile of track will run fully as high, and in many cases higher than the cost of the third-rail installation.

The costs of section-houses, circuit-breakers, and automatic apparatus will be quite as much with an overhead system as with the third-rail.

Tracks in either case must be bonded, more heavily and hence at greater expense for the direct current than for the alternating, but the difference will often be met by features connected with the overhead system, such as extra cost of piers, pull-offs columns, changes necessary in telegraph and telephone circuits, and clearing the right of way from trees.

The remaining element is the locomotive and motor-car equipment; the motors for the direct-current system being operated on the series-multiple plan, with resistance variation and possibly with field shunts; those for the single-phase alternating-current system, except where there is the intermediary of a motor-generator set, through a secondary or autotransformer carried on the car. According to present

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developments, there is here very great difference in the weight and cost of apparatus, and in the number of motors necessary to perform any given service. Judged from every standard which I have been able to compare, the cost of this part of equipment with 25-cycle alternating-current motors is so much higher than that with direct-current motor equipments, that, assuming a reasonable operating potential on the third-rail, it is certainly a debatable question whether the increased cost, and cost of operation of the motor-car equipments will not fully offset the cost of the synchronous converters and the losses in their operation.

I have made many comparative analyses, involving millions of dollars, and I have found that where equal permanence of installation is provided for, and equal ultimate as well as average duty, there is not on demonstrated facts a wide variation in the initial cost of plant.

Ordinarily, the signal systems used on railroads will have to be changed at considerable cost. Fortunately, methods have been developed which permit the use of all the rails for the main return-circuit by using a special alternating-current circuit for operating the signals. Where the tracks are used for direct-current return, reactance bonds are inserted which permit the flow of the direct current, but resist that of the alternating signal current. Where the tracks are used for alternating-current operation, and are likewise subject to the flow of direct currents, the signals must be operated by alternating currents of high frequency through apparatus which is inoperative to currents of low frequency or continuous currents.

Field of the single-phase alternating-current motor. It would be idle to deny, and I have no wish to belittle the good work done and the results achieved in the development of the single-phase motor, just as it would be equally unwise to ignore what has been done in polyphase and direct-current work. The results, whatever they are, are facts which must be dealt with in a judicial spirit; but facts, not contradictory and unwise or unsupportable claims, must eventually guide the engineer. No one can deny that if the single-phase motor be developed to a high state of weight-efficiency, unhandicapped by excessive weight of the collateral apparatus necessary on a car to utilize it, and if the capacity of conductors, especially steel conductors, for alternating currents can by any discovery be raised, the elimination of moving machinery in, and the sim-

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plification of sub-stations would open up a very extended and important field for the use of this type of apparatus.

But with developments as they are at present, what is the actual field? As there is no general agreement as to methods of construction, so, too, I find no fixed conclusions as to the field of commercial usefulness; rather, on the contrary the sharpest differences of opinion. Some, with enthusiastic catholicity, make it all-embracing for steam roads, quite irrespective of well known limitations. Others, although at times seemingly contradictory, are even more elastic in their claims.

For example, one engineer says: " It is recognized that for heavy railroad service, where all kinds of speeds should be obtained economically, the single phase railway system will undoubtedly show to great advantage compared to any known continuous current system." Again, the same authority states: " While suburban work was once thought to be the most important field for the single phase railway, it has now become evident that city work, where traffic is very congested in parts of the system, will prove to be one of the best fields." Another affirms: " Interurban electric traction work is the peculiar field of the alternating current system," but adds to this the statement: " When stops are few, the advantage of the alternating-current system is not so greatly marked. In short runs, the alternating current system can have the greater advantage."

It has even been stated that for such services as that on our elevated and underground rapid transit roads, with their congested train movements, quick accelerations, high schedules and limited clearances, the single phase alternating current motor would find a fruitful field. It would, but the fruit would be somewhat bitter.

It seems to me that the present principal field of usefulness of the single-phase system is on roads of considerable extent which operate an irregular and sparse traffic, and where only a moderately expensive, or what may be called a second-class overhead construction, which will keep down the ratio of line investment to that of the balance of equipment, is tolerable. As one departs from this condition, adopts more permanent construction, and faces the problems of denser traffics and higher capacities, any advantages of the single-phase system will disappear, and a superiority of the direct-current equipment, with such improvements as are in sight, become manifest. But whatever may be the future of single-phase operation under the conditions

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stated, any present claim for it as the preferable equipment for congested service demanding high schedules and great capacity is not worth a moment's thought, for in this field, at least, it cannot touch the direct-current system.

Without individual comment, I quote from the preface of the recent work by Messrs. Parshall and Hobart, "Electric Railway Engineering," the following interesting expression of opinion: "In our judgment, the limitation of the alternating current motor is fixed, in its relation of energy output to weight, by the inherent properties of single-phase commutator apparatus, and the limitation of the continuous-current motor will be determined by the maximum safe voltage at which a commutating machine can be worked. While the development of each class of machine has advanced beyond the point that could reasonably have been foreseen, and while it is impossible at the present time to predict where the limitations will be reached, we are satisfied that a careful comparison of the two types at the present time is decidedly to the advantage of the high tension continuous current motor."

In closing, let me again remind you that we engineers are not omniscient, or immune from mistakes. Feeling strongly and speaking confidently of those things in which we believe, it is not reasonable to assume that the great diversity of opinion which exists, often emphasized by individual experience along specific lines, reinforced by knowledge of what has been accomplished in other directions, and influenced by such personal bias as we are all subject to, emphasizes the necessity of the utmost development in every direction, and the probability, nay certainty, that there is at present no single system which can be selected as best for all purposes; but rather, that a wide and increasing use of each will be created, and in the majority of cases a compromise selection of the best elements of alternating- and direct-current practice will obtain.

While there are many things in railroading which have been standardized, and others which can now very properly be, and which of themselves do not militate against the independent judgment of operating railway officials in matters individual to their own systems, I think it is certain that these same officials will in the future, as in the past, consider the problems involved in a change of motive power from steam to electricity from an individual standpoint, and that they will demand from manufacturers, as well as from their engi-

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neers, all possible freedom from restriction, exercising in a large measure their own judgment as to the adoption of any system. I see no practical necessity to formulate conclusions by averaging conditions, and I cannot conceive the responsible officers of any trunk-line road being guided in their determination of what seems best for their own requirements by consideration of what some road thousands of miles removed in location, and enormously removed in operating conditions may do.

In any case, the most satisfactory system will be that one which will permit of continuous all-round operation under such conditions as will utilize to the utmost all the beneficial features of electric application. If any one system can be demonstrated to meet these conditions better than all others, then that system will become preeminent, no matter what standards may have been adopted or recommended, and no matter what our preconceived prejudices may be.

APPENDIX.

Among the publications containing my views on the subject of heavy electric traction, may be mentioned the following:

National Electric Light Convention, Feb. 1890. Paper on "The Electric Railway."

Forum, Sept 1891. "The Future of the Electric Railway."

American Institute of Electrical Engineers, June, 1892. Inaugural Address: "Coming Developments of Electric Railways."

Engineering Magazine, July, 1895. "Will Trunk Lines be operated by Electricity?"

Electric Power, Nov. 1895. Editorial Views on Replacing Steam Locomotives by Electricity.

Engineering Magazine, Feb. 1898. "The Possibilities and Limitations of Electric Traction."

American Institute of Electrical Engineers, Feb. 1900. Discussion of Boynton's paper: "Electric Traction."

Electrical Review, Jan. 1901. "Historical Notes of Electric Traction."

Institution of Electrical Engineers, Feb. 1901. Discussion of Langdon's paper: "The Supercession of the Steam by the Electric Locomotive."

Engineering Magazine, Oct. 1901. "The Rapid Transit Problem in London."

American Institute of Electrical Engineers, June, 1902. Discussion of Arnold's paper: "Relative Costs of Operating by Steam and Electricity."

Electrical World, March, 1904. "The Past, Present and Future of Electric Traction."

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International Electrical Congress, St. Louis, Sept., 1904. "The History and Development of Electric Railways." Discussion of Arnold's papers: "Electrification of Steam Railways," and "Polyphase and Single-Phase Traction."

Discussion of Dawson's paper: "Electric Traction on British Railways."

New York Railroad Club, Jan., 1905. Discussion of Potter's paper: "Developments in Electric Traction."

American Institute of Electrical Engineers, Feb., 1905. Dinner celebrating Triumph of Electric Traction; "The Art and The Men."

Century Magazine, July-August, 1905. "The Electric Railway."

Street Railway Journal, Oct., 1905. An Unprecedented Railway Situation."

New York Railroad Club, March, 1906. Discussion of Lamme's paper: "Alternating-Current Electric Systems for Heavy Railway Service."

American Institute of Electrical Engineers, Jan., 1907. Discussion of Stillwell and Putnam's paper: "The Substitution of the Electric Motor for the Steam Locomotive."

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Discussion on "The Rowland Telegraphic System," at New York, April 15, 1907.

Ralph W. Pope: First I wish you to join with me in an expression of our appreciation of the esteemed privilege of having with us to-night our first honorary member, and I may say one of our oldest members, Sir William Preece, who has awarded to us the distinguished honor of presiding this evening.

When undertaking to open the discussion on the paper this evening, it was not my intention to go into the technical details of this very remarkable instrument which has been described in the paper before you. My first opportunity of examining this system was at the Paris Exposition in 1900, where it was on exhibition only, as we may say. On Saturday last I had an opportunity to examine the system in actual commercial operation between New York and Boston, and upon one of the worst days, so far as weather is concerned, that could be conceived, which tended to reduce the speed, not only of this system, but of any other system of telegraphy with which we are familiar.

In approaching the discussion of a system of this kind I wish to say we should first divest ourselves of the prejudice against the Morse telegraph, which exists in the case of those who are not practical operators and familiar with the code. To those who have practiced Morse telegraphy, some of those things which appear to be a mystery to others, are like an open book before us. I may say in explanation of my position on this subject that I learned telegraphy on the Hughes printing telegraph forty-nine years ago. I might make it fifty years, but I would not lie for one year. I learned the Morse telegraph as a side issue, simply as a man might pick up the art of playing the violin, without any idea that the Morse system would eventually prevail. The Hughes printer, which was new at that time, was invented by David E. Hughes, a musician in Kentucky, and one of the pair which I first operated was the second then in use, the first, I think, being between New York and Philadelphia, and the second, on which I learned, was between Great Barrington and Pittsfield, Mass., which at that time was an unimportant line. The contempt for the Morse and Bain systems which were in operation at that time may be well expressed by the terms applied to them by the printing operators. The Morse was called the "woodpecker," and the Bain system the "dyetubs"; and any message transmitted by either of these systems, via Springfield, was supposed to be "bulled" as the only system which was known to be "accurate and reliable" was the House printer, on which the Hughes was afterwards grafted. In those days, when an inventor brought out a new system a company was organized to exploit it. Consequently we had in the old times the magnetic, the House, and the Bain telegraphs. The House printing telegraph, the invention of Royal E. House, was a triumph of

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electromechanical skill. It is true that between New York and Boston it could not be worked through, on account of the rapidity of the vibrations, and consequently the Hughes printer, requiring but one pulsation to each letter, was preferred to the House and eventually superseded it. I am giving these instances of the situation at that time.

Now, there is no doubt about the speed of the Morse, the House, or the Hughes, so far as a single wire was concerned. The House was perhaps the fastest, the Hughes next, and the Morse last. Eventually there came about a consolidation, and the House printer was displaced; the Hughes system was transformed by the late George M. Phelps into the "combination" printer, and subsequently into the "motor" printer and was in actual operation up to within a few years ago. It was duplexed, and I might say, although I will come to it later, that the expert operators on the Phelps printer, between New York and Boston, and New York, Philadelphia and Washington, were the highest paid in the telegraphic operating department, so that we may cast aside for the moment the idea that because the letters are on the keys, any fool can be an expert operator.

The telegraph is the oldest, and I will also say the most important development of the modern application of electricity. The electric light has its rival in gas, and the electric railway has its rival in steam, and the telephone is applicable only to comparatively short-distance transmission; but for world wide communication for the general distribution of intelligence, and that application of electricity which would be the last we would part with, telegraphy stands at the head.

The Morse system, as it is known to those who operate it, may be used under the most adverse conditions. Prior to the expiration of the Morse patents, which covered the application of the local circuit and the sounder, the opposition companies were obliged to use simply the relay without the sounder, so that we had to read from very faint sounds. On one occasion I was visited in Exchange Place by an operator from the old American office; it was a wet day, and I had my relay screwed down so that the sound of it was like the ticking of a watch. The office was about one-quarter the size of this stage, and the relay began to tick, and I said, "I am busy." He asked, "What are you doing?" I replied, "I am receiving from Boston." That was a fact; I was receiving on that relay without the local sounder, and he, although only four feet away, could not hear a sound. It might be assumed I was guessing at it, but I was actually reading it.

I am rather wandering over the subject, but I am bringing up the conditions that existed in regard to the Morse telegraph and why it prevails to-day. In 1868 I was quartered in the Gold Room at the time of the "Black Friday" panic. The correspondent at the Boston or Philadelphia exchange was right at the counter. Assuming this platform as the exchange, the

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operator, if he had a message, would call out for the man for whom the message was intended, and he would come to the counter for his telegram. I have sent a message to Boston, and received a reply and delivered it to the original sender of the message, before the ink on the original was dry, probably in the course of a minute. Now, leading up to the instrument which we have under discussion this evening, I made a similar test with Dr. Sheldon, who was with me last Saturday; I sent a telegram to Boston, to be repeated back to New York and delivered to Dr. Sheldon, who was at my side. I handed him the following message in the course of regular business: "Samuel Sheldon, Boston—I will arrange Monday morning for payment suggested, and will adjust the matter with Mr. Carty as soon as possible. R. W. Pope." The message was delivered back into my hands, in printed form, having been sent from New York to Boston and returned from Boston to New York, in five minutes. As a practical demonstration, I am quite satisfied with that, for the reason that my reply was sandwiched in with other commercial messages received in the ordinary course of business, and I wish to say, as the result of our investigation, that four operators were sending to Boston over one wire, and the messages were coming in over the same wire on the four instruments from the Boston end. I consider this a very satisfactory showing. There is a weaker point in the telegraph service than the simple transmission of messages, and that is the question of delivery after the message is received. In my earlier days, when I received a message, I used to close the office for a half hour, during which time I went out to deliver it. I have also known of cases when one messenger was in the office, when two messages were received, one message to go a mile in one direction, the other a mile in the opposite direction, and the question was which of the two messages should be delivered first. That leads up to another point, and that is the classification of service. We have heard from the advocates of the telegraphic system, that all messages should be sent and delivered in the order of their reception, which is well known to be practically impossible. In the first place, the ordinary customer hands in his message over the counter, and it may go to a distant point over one out of perhaps ten or a dozen wires. If he happens to be a broker at the exchange it may go over a special wire, and be delivered in the course of a few minutes, while if it goes in the ordinary course of business over a busy wire, the sender will be lucky if it is delivered in an hour. So that there are some things to be considered in regard to telegraphing outside of the transmission of messages.

Reverting to the system we have under discussion, we must understand that it applies in the main, as most of these systems do, that is, the machine or automatic systems, to the trunk line business, or business between any two large cities, where the volume of business is such that apparatus of this kind can be

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installed and kept in continuous operation. It appears to me that the general use of the Morse telegraph is due to its simplicity, low cost of operation, and its application to all conditions. As I was saying in regard to my learning the Morse system as a side issue, after learning to read by sound, if the Hughes printer broke down we could send or receive a telegram through the bell on the side, using the Morse code. The Hughes printer was based on synchronism. The instruments at each end of the wire were required to be in almost absolute synchronism. If they varied, one of them "threw out," as we called it, and had to be put in unison and started up again. There was a very peculiar instance of the necessity of that unison that occurred to me at the time I learned the business, and that was on the occasion of the first message over the original Atlantic cable in 1858. My brother, who was my superior, had gone away for a day, and I was on duty, and the station twenty-five miles north had been endeavoring for two hours to send me a communication which I could not receive on the Hughes printer. When the train arrived the newsboy on board set off a pack of fire crackers. I inquired what was up, and was told that the Atlantic cable was a success. My brother was on the train. He came into the office and I told him what had been doing. That the office twenty-five miles away had been trying to send something to me for nearly two hours, and that the printer continually "threw out." He looked at the machine, and took a hammer and knocked along the brake governor on the shaft about $\frac{1}{16}$ of an inch. The brake had shifted about $\frac{1}{16}$ of an inch on the shaft and did not strike in the center of the wheel; that was all the trouble. The machine was not quite fool-proof.

In closing I call attention to the author's statement that "In practical operation it has continuously demonstrated its efficiency in dispatching an enormous volume of business with regularity and accuracy on a single wire, while the operators employed have been not necessarily skilled in the use of the Morse code." That is quite true. They do not need to know how to fiddle or to play a snare drum, but all the same it is a fact that the Morse operator who is trained and familiar with the business, if he or she has learned the Morse code they are adapted to telegraph work. So I find as a matter of fact, that the best operators, even the best operators to work a keyboard are those who are trained in the telegraph service and have that intuition or familiarity with the business which makes them valuable employees. Consequently while it is quite proper that they should be trained up to do special work, in the ordinary office, it is better to have the force interchangeable, and if there are Morse operators who are capable of operating the printer system, and operators of the printer system who are capable of operating the Morse system, the interchangeability of that force becomes a rather substantial consideration in the office organization, and I might

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go further and say that while it is no doubt advantageous and economical to install a system which will convey a larger number of messages over a wire, it is still desirable that the systems should be interchangeable, and that the simplicity of the Morse will persist, and while it is true that the Morse telegraph has not been improved for many years so far as the operator is concerned, and so far as the public is concerned, it has been improved so far as the company is concerned, in regard to the greater earning capacity, and by the use of the typewriter, which has enabled the telegraph operator to receive at a higher rate than the sending operator can send the messages.

The speed of the Rowland system, and in fact all the claims set forth in this paper so far as the speed is concerned, and in comparison with the Morse I consider well substantiated. The speed of forty words a minute can be attained by a Morse operator, but it still remains to be seen whether we can develop a system which will send messages four in each direction at that rate ready for delivery, which is 320 words a minute over a single wire. The advantage of the delivery of messages in page form over the old tape printing system I consider is very desirable, and I am glad to know that the Rowland printer has reached its present state of perfection. I can hardly believe that the distinguished inventor would have asked that any better monument to his memory could be erected than the establishment and the continuation of a system bearing his name, and it is my hope that it may be continued and in the future be on an equality with the Morse telegraph of to-day.

A. E. Kennelly: It is remarkable that although electrical applications have developed so rapidly and assumed so important a position in this and other countries, the electric telegraph has almost stood still. In fact, some say that it has not even marked time. A few years ago, in New York City one could pass through the main telegraph office and see a few printing telegraphs. One might have seen a number of automatic Wheatstone instruments, very likely a number of quadruplex sets. I think I am correct in saying there are now no printing telegraphs remaining except the recent ones of the system described here and one other new system; that there are no Wheatstone automatic sets, and that there are fewer quadruplex sets than there used to be. We are struck by the contrast between this apparent want of progress in telegraphy and the progress which has made itself felt in other lines of electrical advancement. It is, however, much easier to criticize destructively than constructively, and there are a number of influences which have been active in this country and elsewhere to account, in part at least, for this apparent want of progress. First of all, the telegraph is the only apparatus which has maintained its original ground and kept on the earth. Everything else electrical has been driven off the earth. Telephones have been driven off the earth, to take shelter in metallic circuits. Even so huge

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a machine as the railroad motor has been virtually driven off the earth. The telegraph has stood, and at considerable disadvantage to itself, because it not only suffers from its own internal disturbances, but also from vagrant disturbances due to other systems in its neighborhood.

I think I am correct in saying that each man, woman, and child in the United States does not send more than about one telegram a year on the average. On the other hand, there are about five million telephones in the country, and the number of conversations by telephone of each man, woman, and child is something like two-thirds of a telephone message a day; this means a difference of, roughly, a message a year, and a message a day, in the two systems, respectively. It is the convenience and growth of telephony which has tended to keep progress in telegraphy in abeyance. The rate of growth of telegraph messages has been slower than the rate of increase of population, according to recent published reports. We seem to have reached rock bottom in the matter of economies. It does not seem possible to get a more economical operation of the system, and consequently anything which will enable us to rob the mails more than we do now, in the use of the telegraph, must be effected by some entirely new method. At the present time there is not only the fixed charge upon lines and apparatus, but the cost of the operator's time at the originating station, at the intermediate stations, and at the receiving station. These costs seem to be impossible of elimination on the Morse system.

We cannot flatter ourselves that any system such as that which has been described to-night will eliminate the Morse system everywhere. The Morse system is admirably adapted not only for way traffic, but also for through traffic of not great pressure. We can only hope for something to take the place of hand telegraphy where the telegraph traffic is great and the pressure keen. If traffic is to increase, there can be but two ways of handling it. One is to duplicate the Morse circuits, to duplex and quadruplex them, if possible. The other is to have something entirely different, Here is a system which offers something entirely different. We must have something which will eliminate the telegraph operator on high-pressure trunk circuits. The hand Morse must be eliminated. The Wheatstone system did that in part, because it enabled a number of sending operators to work together on one wire, and the same number of receiving operators to work together on the same wire; but here is an apparatus which will enable the Morse code to be completely eliminated; a simple mechanism to be operated from both ends of the line, keyboard to keyboard, typewriter to typewriter. That is an ideal system, if the inertia of the removing parts can be reduced so as to make the speed of the same order as that which can be secured by instruments of the Bain type. I am sure we hope that this apparatus,

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and others of similar type, may so far develop as to bring progress once more to the neglected art of telegraphy, and let us have a chance to relieve the hands of the operators, without reducing the demand upon their skill and intelligence.

William Maver, Jr.: It is true that telegraph engineers and managers admit that the ideal system of telegraphy is one in which the messages may be transmitted without previous preparation at a high rate of speed and be received accurately at a distant station on page form in printed Roman letters. There have been many difficulties in the way of producing this ideal system, and therefore the degree of success which has been reached by the Rowland system, and I might also say by the Buckingham, Barclay, and Murray systems, is most encouraging. I have long pondered on what set Professor Rowland's mind in the direction of multiplex telegraphy. I do not think it could have been the idea of making money, because we all know it requires the purse of a millionaire to bring into practical operation, or even into fairly practical operation, a multiplex telegraph system. I have heard of one inventor who has spent more than $150,000 in the attempt to do so, and recently I saw a statement to the effect that $9,000,000 has been expended in the last decade in the attempt to perfect printing telegraph systems. I do not know that these figures are strictly accurate, but even if cut in half they would suffice to illustrate the point.

I had the pleasure of seeing Professor Rowland's original apparatus some years ago, and it certainly was somewhat crude. At that time if I remember rightly it was a tape printer. Before Professor Rowland passed away—too early I think—the system had undergone two complete changes, and since then I believe it has undergone four more radical changes. To-day it is in a very fair state of practical operation. I saw the system in operation, as Mr. Pope saw it, last Saturday, working between Boston and New York, on the lines of the Postal Telegraph Company. It worked very nicely. I think, however, that it is necessary to make some qualification or amplification of the Mr. Potts' statement, with reference to the efficiency of this system in meeting the requirements of commercial telegraphy. In fact this system is in operation on one wire about 280 miles in length, as an octoplex; that is to say, eight messages are transmitted by this system simultaneously at a certain rate of transmission. To apply this system to a circuit between New York and Chicago will most likely entail some modifications; as, for instance, the reduction of the capacity of the system from that of an octoplex to that of a quadruplex. It will also require the introduction of an automatic repeater midway of the circuit, the practicability of which has not as yet been tested out. As Mr. Pope has pointed out, the system is not applicable readily to way wires and certain other circuits. The capacity of the system is given as 600 messages per hour; this, it should

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be noted, is the maximum capacity of the system when operated as an octoplex on comparatively short overhead wires. On long circuits this capacity will be, it is probable, materially reduced.

There seems to be no question as to the utility of the Rowland system on the comparatively short circuits to which it has thus far been applied. The matter of general reliability, accuracy, and cost of operation of the system are probably yet to be determined. I believe Mr. Murray has intimated that he considers his system better adapted to long circuits than to short circuits, presumably because of the necessity for preparing the messages in advance for transmission, etc. On the other hand, it is possible that the Rowland system may find its best field on comparatively short lines.

The author states that the basis of the telegraph current used in this system is an alternating current. This is of course true, but it is a somewhat singular fact that the actual signaling currents are made up of pulsations of continuous or one-direction currents. This is evident from the oscillograms. The accuracy of this remark will also be apparent from the fact that if, for example, a signal is to be made by normally negative impulses Nos. 2 and 4, and if we assume that the impulse before impulse No. 2 was a normal positive impulse, then impulse No. 2, when it is reversed, will also be positive, which gives the desired reversal, so called. Similarly impulse No. 4 will be preceded by a normal positive impulse. Consequently, when impulse No. 4 is reversed it will be followed by a normal positive impulse. Therefore in this and numerous other combinations for signals, there will be five successive positive or negative impulses. Hence the "clearing out" effects of alternating currents are not fully obtained. The currents used in signaling in this system are indeed virtually akin to those employed in submarine cable signaling.

The author states that the current strength necessary for the operation of the relays of the Rowland system is about 35 milliamperes. It is interesting to note that this is about the current strength required in the operation of the ordinary Morse duplex and quadruplex relays.

The author implies that the presence of the human element in the Morse system introduces corresponding inaccuracies. I have the honor to differ somewhat with him in what he implies in that statement. It has long been an axiom among telegraph managers and engineers that the receiving operator of the Morse system is a continual check upon the sending operator. In many cases in actual practice the receiving operator instantly detects and corrects or prevents errors of the sending operator, as well as the errors or omissions that would be frequently caused by momentary line trouble, and which no mere machine at the receiving end could do.

At first sight, this highly ingenious telegraph system may

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appear somewhat complicated. This impression, however, wears off with a clearer knowledge of the apparatus; for it is apparent that the seeming complexity is due more to the necessary multiplication of the parts than to the intricacy of the system as a whole. The engineers of the Rowland system are to be congratulated on the success they have thus far achieved. They are fortunate in now having the system in operation under practical conditions, where its defects, if any remain, will become apparent and when opportunities for further development and improvement of the system will doubtless be found.

Henry G. Stott: In reading over this paper, it occurred to me with a great deal of pleasure that to-night I was to take part in a meeting at which Sir William Preece was to preside. I experience this pleasure largely because over twenty years ago, when I studied electricity under Professor Andrew Jamison, our text-book on telegraphy was one by Preece and Sieveright. Now we come to the fountain-head for more information on the subject of telegraphy. I think if we had the book here to-night it would be found that very little has been written into the progress of the art since that volume first became a text-book.

Several of the public-service corporations have recently been forced to increase their rates. No board of directors deliberately sits down and increases the rates for its service just for the pleasure of doing so; the only thing that prompts them to do this is in the realization of a grave duty to the stockholders. True, the cost of copper has gone up 100 per cent., and the cost of labor 50 per cent. in the last ten years. But why is it that telegraph rates have had to be increased, while electric-light rates, power rates, and telephone rates have all gone down?

Some time ago Mr. Pope called to my attention a letter which he received from a telegraph engineer in the West. The letter was in the nature of a complaint against the Papers Committee, of which I am a member, and said: "Why do you have so many papers on lightning arresters, electric railway motors, and things of that kind, and you never give us a paper on telegraphy?" I shall try to answer that letter here.

Why do the other gentlemen, who present elaborate papers on lightning-arresters, railway problems, features connected with transmission lines, etc.—why do they come here with these papers. Simply to get the benefit of the criticism and comment of their co-workers in these fields. How many papers have we had presented on telegraph subjects in the last ten years? I think this is the first one that I can recall, but I trust that it is only the precursor of many equally important papers, and that the period of stagnation in the development of telegraphy is at last at an end, and that the rapid development by our members of automătic apparatus, such as that described in to-day's paper, will enable our Telegraphic Companies to progress as rapidly as the other electrical industries.

E. F. Northrup: I have in hand a small piece of paper which speaks of the human side of the development of this system of

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telegraphy. I am reminded that it will be six years to-morrow morning since Professor Rowland died. Mr. Maver said this evening that he wondered why Professor Rowland turned his attention to telegraphy. I think I can answer that question, for I was with Professor Rowland at the time that he began to be interested in this telegraph. I acted as his assistant in its development for three years previously to his death and I had the exceptional pleasure of spending two weeks with him at his cottage at Seal Harbor, Maine, and there heard from him why he devoted himself to the development of his telegraph system. He had a disease which he knew would probably be fatal and he could not get a life insurance. He told me he had many problems in physics of the highest importance that he would love to work out, but that he felt that it was his duty to try to leave his family a heritage that would have a monetary value. He was the most courageous man that I ever have known. He worked on his telegraph almost to the day before his death, as this paper will attest. Three days before his death I received this note written by him on his sick bed:

Put in patent condenser, also coils; duplex of many lines so as not to interfere with each other. You do not know this; come and learn. H. A. R.

I went to his house and got his instructions while he was on his sick bed.

I worked on the telegraph for a year after his death, but I cannot take time to speak at length regarding the technical features of this system with which, at one time, I was very familiar. I may say, however, that the system is peculiar in this respect, that it is a kinetic system as distinguished from a static system. I mean by this that normally current is passing over the line at all times and not at a time only when a signal is being sent. The system presents, however, this paradox, that when a signal is being sent at the same instant from opposite ends of a duplexed line, there is at that instant no current on the line. The signal is made by stopping the vibrating tongue of a relay, while in most other systems a signal causes a relay tongue to move.

One feature, not spoken of to-night, is the immense flexibility of the system in the matter of the distribution of the lines and messages. Professor Rowland laid the foundations of innumerable methods for the distribution of the messages which the flexibility of the alternating current admits.

Gano Dunn: It is some years since I used to pound a key, but I love it still and trust I may be pardoned a tribute of affection to the telegraph business, because the telegraph business opened to me the door of a college education and an electrical career. It took me from a dingy office haunted by messenger boys to this glorious building which speaks a development of the electrical industry far beyond the dreams of the early telegrapher. The old Morse systems had in their ranks

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nearly all the men who later started this electrical development and I feel proud that I am, as it were, a member of the old union. It is fitting that this first evening of the week of dedicatory exercises should be devoted to a telegraph meeting.

If the paper presented to-night were read by the general public, especially the paragraph which rates the capacity of the new system at 600 messages per hour, the public would be inclined immediately to ask Mr. Clowry, who in the newspapers a few days ago explained the increase in rates of our large telegraph companies, how long it will be before these rates shall be again reduced to a very small amount, in view of the enormous difference between 600 messages per hour per wire and 17 messages per hour which he referred to. If not qualified, this paper would give the public a false impression. It is not the capacity for transmission that limits the telegraph business to-day, for actual transmission is the least part of all the business involved in the receipt and delivery of messages. The Rowland system, beautiful as it is, a system which I believe will come into large use, is, after all, applicable only to trunk lines between large cities, to places where there are experts to watch it, places where its use will be justified by the volume of business.

I doubt if the Rowland system will ever drive out the old instruments. Their simplicity and reliability have won for them their present place. The fact that we still have them testifies eloquently to their fitness. It does not testify to stagnation in the technical development of telegraph systems.

In the Rowland system the typist takes the place of the operator, but the typist is seldom qualified to rearrange damaged or displaced parts; and these things happen sometimes in a telegraph office when the manager's back is turned, for boys occasionally throw ink-wells that put the apparatus out of business. I have seen 150-ohm relays and the rest of the accompanying Morse outfit unmindful for years of everything that was thrown at them.

The grounds for the statements I made of the limited field to which the Rowland system may look forward are in the proportion already existing between quadruplexes and single lines. Roughly speaking, there are 30,000 offices in this country. Notwithstanding the fact that the quadruplex is cheap and yet increases the wire capacity nearly four times, I doubt if there are 3000 quadruplexes in use. If there were the great demand for increased wire capacity, which the advocates of the machine telegraph and multiplex systems generally take as their starting point, we should see more quadruplexes. The proportion mentioned indicates the balance between the advantages gained by their introduction and the accompanying disadvantages of inflexibility and complications.

Although the Rowland system will increase the wire capacity eight times that of a single wire, and claims an increase in oper-

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ator capacity about three times, and makes further claim to increase in operator capacity by not requiring a receiving operator (although making no allowance for the skilled mechanician that would be needed) I believe that these great advantages will be almost counterbalanced by the enormous complication of the apparatus. If Mr. Kipling should write up the telegraph business, the Rowland system is what he would call an eight-day clock.

I think the success of the Rowland system must be looked for in large offices where there are trained experts, and a high degree of organization. It is my opinion that for many years to come ninety per cent. of the clicks we shall hear over the length and breadth of the land will be good old "Morse."

Sir William Preece: I think the hour has arrived when we had better close this discussion, but it will afford me an opportunity to play the same role that Mr. Pope has played and refer to my early years and the memories of the past. My career commenced in the year 1852, so that I have had 55 years' experience, while he said 49; he was afraid to say 50, like the man who shot 999 ducks and would not admit that he had shot the thousandth. Fifty-five years' experience in all branches of practical telegraphy gives me the privilege and honor of saying that I have had something to do, directly or indirectly, with every single practical application of electricity. I commenced first with the telegraph, and my heart still goes out to the telegraph. In my early days I was brought into contact with Faraday—I believe I am to-day the only living pupil of Mr. Faraday. My early acquaintance with Dr. Kennelly was in poring over Faraday's Researches. In 1853 we laid down underground wires between London, Liverpool, and Manchester, 212 miles long, and we had serious effects due to static induction. We did not understand it. We called in Faraday and Sir George Wren, who was then the Astronomer Royal, and I worked with these two great philosophers for many months and carried out all the experiments Faraday wished to have carried out. I still have some of the records.

The first automatic system of telegraphing was that invented by Bain. The currents were transmitted through punched paper, and marks made on strips of paper saturated with prussiate of potash. They were blue marks, and I have many of the records made in those days to show the influence of static induction in retarding and in elongating the currents that came out at the distant end when a mere dot was introduced at the sending end. Many years after this, my first acquaintance with Edison arose from his coming over to England with an automatic system based on this chemical recorder. He had placed at his disposal a cable coiled in one of the tanks in the cable makers' works. He asked me what I thought would be the length of a dot through a thousand miles of cable. I had in my mind a thousand miles of cable laid out straight, and I told him

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I thought a dot would come out about six inches long. He said, "What do you think it would be in the case of a cable coiled in a tank?" I said, "I really cannot tell." "Why," he said, "I wanted to know what the length of that dot would be, and when that dot came out, what do you think it was? it was 28 feet long!" That was Edison's experience with the effects of static induction. It was an experience of great service to those who are transmitting currents through long underground cables. That led to a very extensive system of underground cables, and no doubt we shall learn a good deal of the influence of the alternating current in working to great distances. I commenced with an automatic system that transmitted 1500 words a minute. It was competent and capable of transmitting 3000 words a minute. Why didn't we use it? Because there was no business for it. This question of automatic versus manual telegraphy is, after all, a question of business, a question of the number of words one wants to transmit, not the number of words one can transmit. In the last fifty years I have been engaged in developing automatic systems of all kinds, but the one in which I am peculiarly interested is the Wheatstone system. When I left the post office service in 1889 we had worked up the Wheatstone system so that it would give 650 words a minute on our longest circuit. We did not want 650 words, for the simple reason we did not have 650 words a minute coming in. It is a question of the messages to transmit, and those having practical knowledge of the working of the telegraph system know this—that in the telegraph business of a country there is a curve precisely similar to the curve we know so well, the load curve of the generating station, for whatever purpose it is used. Messages come pouring in according to the business hours of the day. In England we have a peak load every morning between 11 and 12 o'clock. It subsides during luncheon hour, and comes up again in the afternoon. In England there is only one time over the country, here in America there are four times, Eastern, Central, Mountain, and Western, and consequently there are peaks at different times of the day. There is three hours difference between San Francisco and New York, and the result is the load curve for business in this country is different from the load curve in England, and therefore no fair comparison can be drawn between the rate at which the messages are transmitted per day or per wire between the two countries. In the last analysis what is wanted is the very best system that will carry the work through to the best advantage of those who use the telegraph.

I discussed this question some years ago with Dr. Green when he was president of the Western Union Telegraph Company. This is my fourth visit to the United States, and whenever I come, my first object has always been to visit the two telegraph companies and learn what progress they are making. I come here to learn, and if I see things done in a manner that

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is contrary to my judgment, I do not hesitate to criticise them; on the other hand, if I find things meritorious and worthy of commendation, I adopt them on the other side and give full credit to those who have produced them on this side of the water. In discussing these things with Dr. Green, he said to me, in the decisive manner he had, "In this country time is our only competitor." What he meant was, that the time elapsing between the moment the message was written and the moment it was delivered, was the time they wanted to control, that was the only thing he feared.

In England I think we have the automatic system in a state of perfection. I do not think there is any system that will beat the Wheatstone for business as it is. It may be that if we increase our load-curve and get a load-factor for the whole day of 50 or 60 or 70 per cent., then we will want automatic systems. At the present time there is no real need in our part of the world—I do not know what it may be here—for any automatic system which will send more than 200 or 300 words a minute, and that we have. It may be that the business will increase and necessitate such a thing. Automatic work is essensential and absolutely imperative on submarine cables, but submarine cables are different from the aerial wires we use. There is a great distinction between telegrams which are always short, and news work which is very considerable at times. In England it is enormous. In England our news business is much greater than in this country. We are all in a compact little island. There is not a single country town of any magnitude that does not issue an evening paper full of news sent by automatic telegraph, and there we find that 400 words a minute is ample to supply all the newspapers with what they want. It won't come in any quicker. A man making a speech, who wants it to appear in the next morning's paper, does not speak over 110 to 120 words a minute. I am not speaking to you now at a rate of more than 110 words a minute, and if there were a shorthand writer here who was reporting my remarks for the purpose of sending them to Chicago, for instance, it would not require an instrument that could work 1500 words a minute to send 110 words a minute. I want to point out that however new and perfect an automatic system may be—and I must say this is a beautiful instrument—there will always be some features concerning it which may not be entirely satisfactory. I had a good deal of correspondence with Dr. Rowland on this very subject, as he was anxious to make a start in England. We lost him too early, as he was one of the most brilliant scientific men of the age. His work will live for many years.

I take it the effect of the discussion to-night has really been, not to bring out very strongly the relative merits of manual telegraphy and automatic telegraphy; but it has raised this one question, and a very important question, and that is the value

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of labor in the telegraph service. In our younger days, Mr. Pope and I, when we used the key, thought ourselves howling swells because we could not only send messages, but we could absolutely and instinctively see a fault or error. When you are at your instrument, you know it like you know your child or wife. The instinctiveness with which an experienced telegraphist can trace a fault is quite wonderful. We take a great deal of pride in our knowledge, but it has this great defect in our country—it has caused our telegraphists to suffer from that complaint which is generally called "swelled head." There has been a good deal of trouble over there. The tendency has been to develop as much as we possibly can these automatic systems rather than to bring down the gentleman whose size of hat increases rather too frequently. It is rather a misfortune, but the development of the brain, in the great growth of business, is one of those things which cannot be helped. I think Mr. Dunn referred to the complication of these systems. That of Dr. Rowland is a combination of others. The synchronism was invented by Hughes; the breaking up of a circle into several divisions transmitted by switch systems was invented by Bain. It was tried a good deal and made practicable by Baudot in Paris, and it is working over submarine cables between Paris and London with a considerable amount of success. You have the alternating current introduced by Crehore and Bedell. There is really little novelty in the principles used, but there is considerable ingenuity shown in the mechanical arrangements. One likes to see a good thing worked up and put into practice. I have done a great deal in introducing automatic apparatus. It seems that we all want to meet the views of Dr. Green. We want to lick time. We can only do that by having means to transmit a message as rapidly as possible from the sending end to the receiving end. The conception of using a wire for many circuits, octuple, as in the Rowland system, is certainly a very great advantage. The reason why the quadruplex has not grown much in England—and I do not think it has grown much in this country—is because of the fault that it "throws out," and you lose the advantage of quadruplexing with four circuits, or octuplexing with eight circuits. Therefore a fault on the line with these systems is very serious. That is the reason why there is a tendency to fall back on the duplex method. The tendency was to use copper very much for speed, but the price of copper has gone up so much it has rendered that practically impossible.

I am sorry to have kept you so long. I have been exceedingly interested to-night in taking part in this discussion. It has been one of the principal studies of my life, as I have told you, and it is like renewing one's childhood almost, to come back here and take part in a discussion of something that I studied over fifty years ago. I can only repeat what I said, that my coming to-night has been a source of great pleasure to me. I

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come here and meet familiar faces, some of whom I meet on the other side, and many more, perhaps, that I meet only when I come here. I find that marine architecture has done much to make the journey across the Atlantic a matter of luxury. Brittania is said to rule the waves, but marine architecture to-day rules the spirit of the waves. We passed through three very severe gales. We never had the fiddles on the table, and I never saw a sick person on the ship. One is in a beautiful palace for five or six days,—it will soon be four and a half days,—from Liverpool to New York. I imagine in the future it will be a simple thing for a man to come from England, attend one of your meetings, and the next day take a steamer back home. There is one thing in which you fellows beat us horribly, and that is in your delightful hospitality. It is not mere hospitality, it is not the fact of the hospitality, but it is the way you do it. I do not know why it is, cannot tell you, but I assure you every time I cross the Atlantic and come here I find the gentlemen treat me in such a pleasant way that if I am spared I will come over again as soon as I can get away. I again thank you most heartily for all the courtesies which have been extended to me by your members.

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REGENERATION OF POWER WITH SINGLE-PHASE ELECTRIC RAILWAY MOTORS.

BY WILLIAM COOPER

The conditions necessary in order that an electric motor may operate successfully in regenerating or restoring power to the supply circuit are:

1. The counter pressure generated by the motor must be greater than the impressed pressure of the supply circuit.
2. The value of this excess counter pressure must be under control and maintained in suitable relation to the impressed pressure.
3. There must be at the time other power-consuming devices connected to the supply circuit.

There is no difficulty in producing the first condition; the second is the one that is difficult to fulfil. There are two methods of regulating the counter to the impressed pressure; one is to increase the counter pressure and the other to reduce the impressed. The third condition, except in isolated cases, will be taken care of by the operating load.

Practically all variable-speed railway motors are of the so-called series type, and as this type of motor is the only one having the proper characteristics for general railway work it alone will be considered. The operation of a series dynamo electric machine as a series generator on a constant-potential circuit is a problem which many have grappled with, but none has solved. The machine must be given a shunt characteristic of a greater or less degree in order to make such operation possible. A machine having the shunt characteristic predominant is unfit for use as a railway motor, and as this characteristic must be predominant to operate

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successfully as a generator it is at once evident that the motor must be changed in some manner before it can be used as a generator. But this is not the only condition which the motor must fulfil in order to operate successfully as a generator in restoring power to the supply circuit; the motor must operate satisfactorily while the armature current is varied through a wide range with a constant field. This is evident from a very casual observation of the conditions.

Assume that the car or locomotive being driven by the motor under consideration has attained a balanced or free running speed under the conditions. The motor is then developing only sufficient torque to overcome the train resistances. The motor, being a series machine, has the same current in the field and armature. Under these conditions a very slight increase in the field current would increase the counter electromotive force of the armature to a value greater than the impressed electromotive force of the supply circuit.

Now assume an ordinary series motor in which the armature current cannot be increased materially above the corresponding field strength without disturbing the commutating conditions; it follows that the motor acting as a generator can only give a retarding force approximately equal to the train resistances. This added to the train resistance would give a total retardation so small that it could not be called a braking effect. From this it is obvious that the armature current must exceed the field current at times in order to produce a retarding effect which can be utilized in bringing the train to rest, or in holding the train on a grade. This, then, is another condition which the ordinary series railway motor does not readily fulfil.

From the foregoing it would seem that a motor to operate successfully as a regenerator of power must have the following characteristics:

1. It must be capable of operating through a wide range of variation between field and armature current, and

2. It must be provided with some means of producing a shunt characteristic.

The first characteristic exists to the fullest extent in a motor having some means of compensating for armature reaction, as well as a means of maintaining a constant commutating condition. This characteristic also exists to a limited extent in a motor having either one of these functions.

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The second characteristic is not so easily provided. In the direct-current motor it can be obtained by providing the motor with both a shunt and series winding, either of which has sufficient capacity to operate the machine either as a shunt-wound generator or as a series motor.

Another method of furnishing the shunt characteristic is to provide a means of separately exciting the motor field independent of the line or motor voltage. There are several ways of doing this. In the case of four-motor equipments, one method is to use one motor as a generator to excite the other three motors which will operate as generators, being connected to the supply circuit.

Storage-batteries may also be used to excite the fields, but this arrangement has its disadvantages in being complicated.

The great difficulty encountered in operating direct-current motors as regenerators of power is that the impressed pressure is a constant, and the means at hand for meeting it are very limited. As the ordinary series motor will not permit of any very great variation of armature current with a constant field, and as only a very limited number of combinations of the motors is possible, the range through which an equipment can be operated regeneratively is, under the most favorable conditions, very limited.

In the single-phase, alternating-current motor of the series type these necessary characteristics are inherent. Without entering into a description of this motor, the design of which is well known, it is sufficient to say that the machine is provided with a compensating winding to neutralize the armature reaction, and also has preventive leads between commutator and armature windings which assist in commutation. This construction yields the first characteristic; the second is easily obtained in connection with the transformer used in the voltage control of the motor.

The method of producing this result is to use one of the motors of the equipment as an exciter for the others. By providing the transformer with suitable voltage taps, the value of the field current of the exciter may be varied through a wide range, as well as the generated voltage of the restored power. In this respect the conditions are very much more favorable than in the case of the direct-current motor, in which the only variations that can possibly be made are in the series-parallel combinations of the motors that are being used as generators.

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The exact arrangement of the motors and their connections are shown diagrammatically in Fig. 1.

Assume the car or locomotive upon which the motors are mounted to be in motion, the armatures turning at a corresponding speed. If the field of the first machine be connected to the transformer, an alternating electromotive force will be generated by its armature, the value of which will be directly proportional to the speed. If the field of the other motor be connected to the exciter armature, an alternating current will pass through it, and the second armature will in turn generate an alternating electromotive force the value of which varies about as the square of the speed—the excitation of the first machine remaining constant.

The electromotive force generated by the second armature will bear a very close phase-relation with the electromotive force

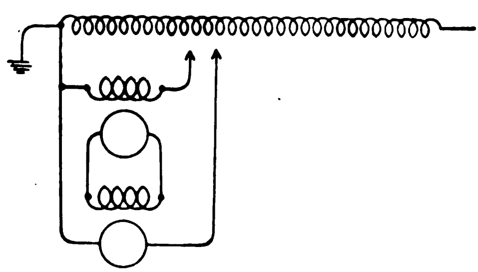

FIG. 1

of the transformer, for the reason that the current in the field circuit connected to the transformer lags approximately 90°, as does the current in the field-circuit of the second machine. This combination throws the generated electromotive force of the second machine approximately 180° back of the transformer electromotive force, or, by reversing the connections, in the same phase-relation.

The phase-relation between the generated and transformer voltages is shown in Fig. 2.

This record shows that the two electromotive forces are in exactly opposite phase. Under these conditions the current flowing after the circuit is closed with the connections reversed, will be displaced from the electromotive force, due to the impedance of the armature circuit. Fig. 3 shows this displacement when the armature is carrying about 100% current overload.

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This is at a power-factor of 80%. The power-factor varies between this and 100% as the load decreases to zero. The obvious method to improve the power-factor is to shift the phase-relation of the generated to the line electromotive force. The result of this is shown in Figs. 4, 5, and 6.

Fig. 4 shows approximately the relation of the generated to the transformer electromotive force as it would be on open circuit, as the current in this case is small.

From these records it is evident that there is no difficulty in restoring power with a single-phase, commutator-type motor at practically 100% power-factor, the machine operating as a non-synchronous, alternating-current generator.

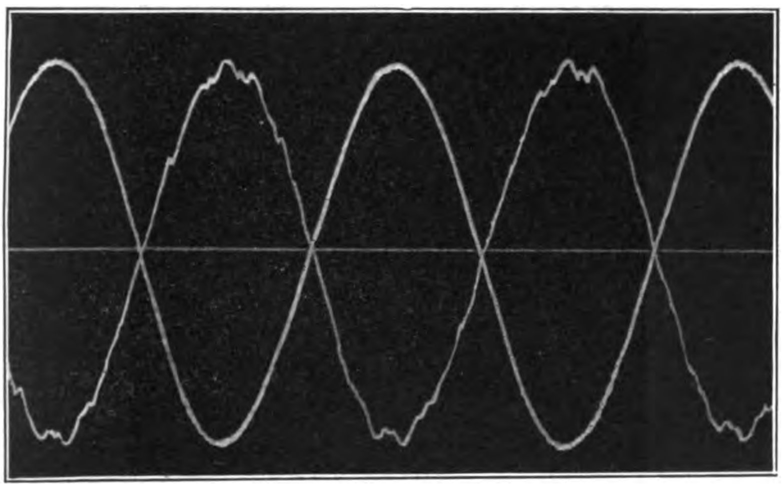

FIG. 2—Oscillogram of generated and transformer electromotive forces. The generated electromotive force is the curve with the irregular top

This condition being established, the next step is to see how it applies to actual operating conditions. From the foregoing it is evident that one of the motors of the equipment must be set aside for use as an exciter for the others, or a separate motor-generator set must be provided. If a separate source of excitation is provided, all the motors can be used to the fullest extent for regeneration of power, in which case the total capacity for regeneration will be increased over the capacity of the machines as motors by the increase in the power-factor. If the regenerative function is to be used for braking in making frequent stops, it might be desirable to supply the separate excita-

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tion; but if it is to be used in holding the train on grades it is unnecessary, as the remaining motors, if the equipment consists of three or more motors, will have ample capacity to do the work.

Assume a 2% grade of considerable length. The motors, all working, have sufficient capacity to haul the train up the grade. Assume the equipment to consist of four motors. Assume train resistances at six pounds per ton. The total tractive effort will then be 46 pounds per ton in ascending.

To hold the train at the same speed in descending, a retarding force of 34 pounds per ton must be supplied. The retarding

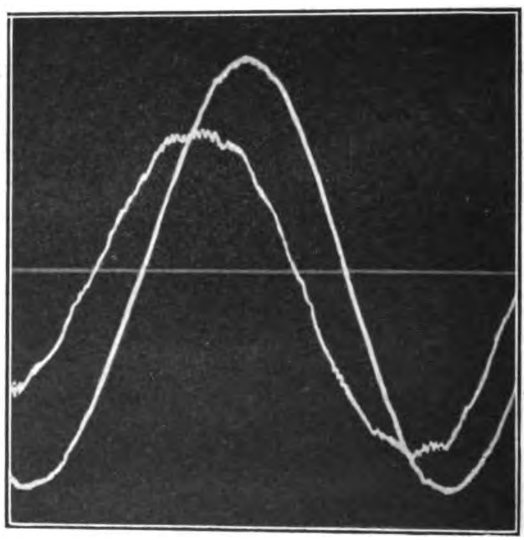

FIG. 3—Oscillogram of current and electromotive force of generator. The lower curve is the current. Power-factor 80% lagging current

force necessary is then approximately 75% of the force necessary to haul the train up the grade. It is evident from this that three of the four motors have ample capacity to exert the necessary retarding force, even if the power-factor of the machines as generators is no better than when they are operating as motors. It has been shown that the power-factor when operating as generators can be made better than when operating as motors; therefore, there is a surplus of capacity in four-motor equipment, and in three-motor equipment about an equal capacity.

The characteristics and capacity of the machines being

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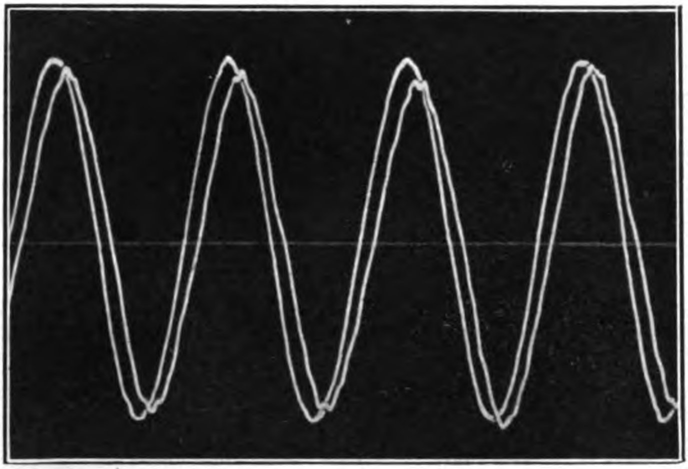

FIG. 4—Oscillogram of current and electromotive force under light load. The lower curve is the current. Power-factor 98% leading current.

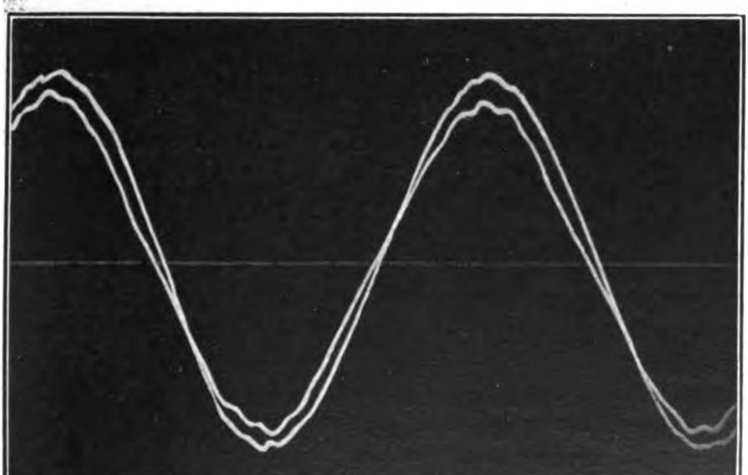

FIG. 5—Oscillogram of current and electromotive force under normal load. Conditions same as Fig. 4 The lower curve is the current. Power-factor 99.5% lagging current

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correct for the work, it only remains to provide suitable means for manipulating the circuits to adapt the apparatus to the conditions. This is accomplished by providing switching apparatus to connect the motors in the proper relation and for furnishing and controlling the field current of the machine used as an exciter.

Fig. 7 shows diagrammatically the main circuits and connections for a four-motor equipment. From this it is evident that the switches used must have a current capacity the same as the motors, for there are four in parallel on the transformer and the switches used for reversing carry the current for one motor

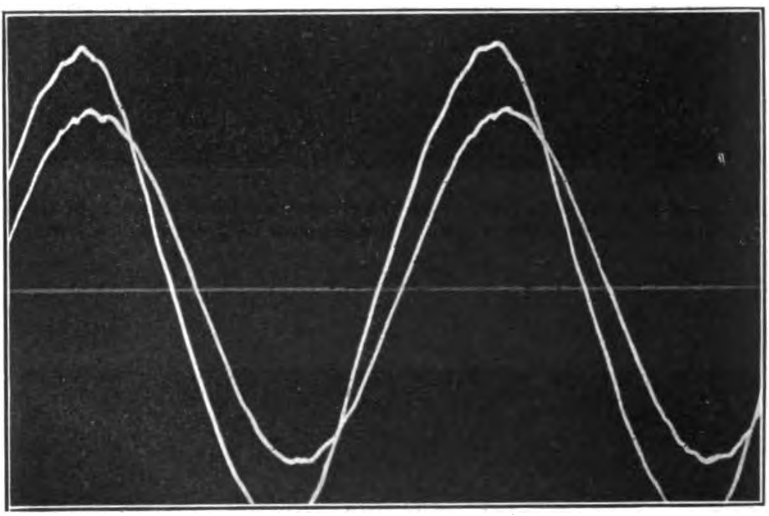

FIG. 6—Oscillogram of current and electromotive force under 100% overload. Conditions same as Figs. 4 and 5 .Power-factor 97% lagging current. The current is the upper curve.

only. As shown, 36 switches are required for the entire control of the motor equipment.

Fig. 8 shows diagrammatically the same motor equipment arranged for regeneration in addition to the regular motor control. As shown, 54 switches are required of the motor-current capacity, and 16 of one fourth that capacity. Of the added switches of the motor-current capacity, 10 have been added to the transformer to enable slow speeds on regeneration to be obtained, and 8 are required to change the combinations of the motors. Besides the added switches, three small preventive coils and a few additional transformer taps are required. From this

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it is seen that the amount of additional apparatus required is insignificant compared with the result accomplished.

The curves shown in Fig. 9 give the relative tractive and re-

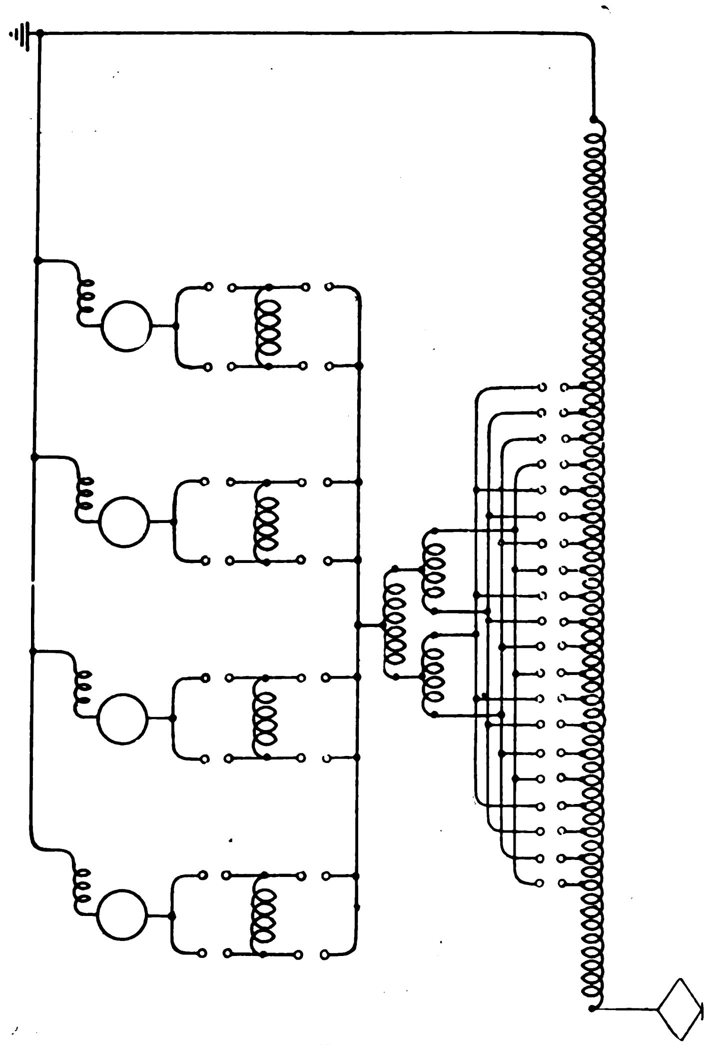

Fig. 7

tarding effort, both continuous and maximum, of a four-motor equipment.

As shown by the curves in Fig. 9 the three motors of a four-motor equipment acting as generators restoring energy to the

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line will let a train down a 2% grade at any speed from 9 miles per hr. to 30 miles per hr., that the motors have capacity to haul up the same grade at any speed up to 18.5 miles per hr. This is for continuous duty. At maximum duty for short periods the

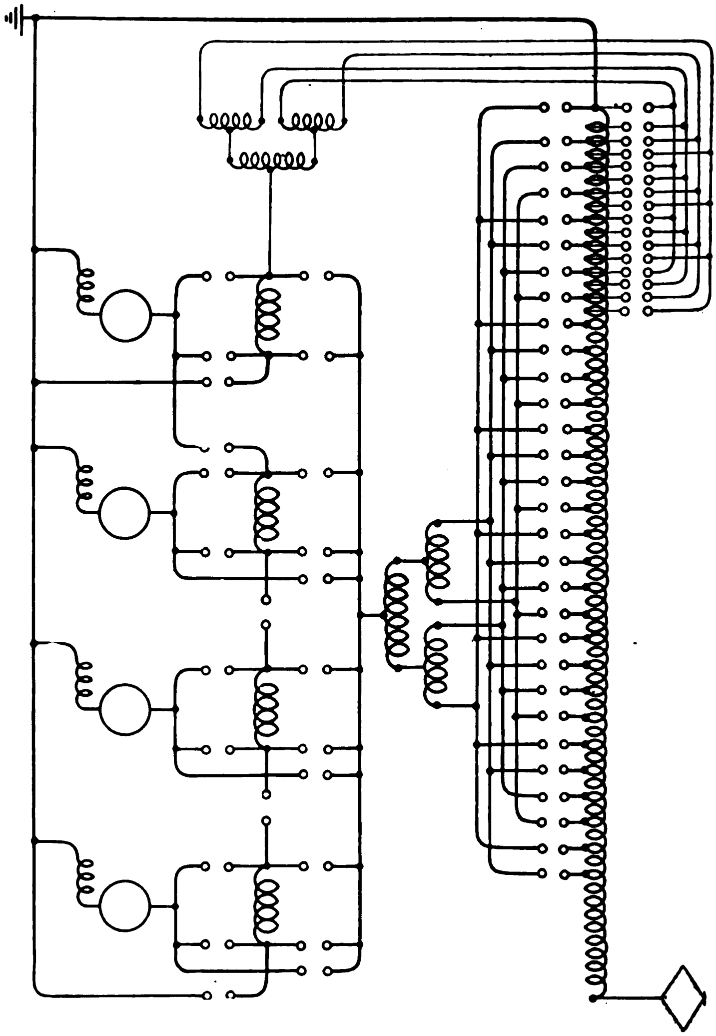

FIG. 8

capacity is increased about 60%. Between 9 miles per hr. and 30 miles per hr. there are 40 operating speeds, the gradations from one to the other being such that at no time will there be any variation exceeding 10% in torque. This necessitates, of

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course, a rather large number of switches being used, but it seems to be a very desirable condition to fulfil in heavy freight traffic.

Efficiency of this system of regeneration. The efficiency of the system when the motors are operating as generators and restoring energy to the supply circuit is about the same as the efficiency when operating as motors, there being perhaps a slight advantage in the case of the generator, due to the improved power-factor conditions. This, of course, assumes about the same load conditions on the machines in either case. However, the actual saving in power-house output can never be a very large percentage. If the entire road consisted of 2% grades and there were no switching to be done, the saving in power consumption might be as high as 50%; under ordinary condi-

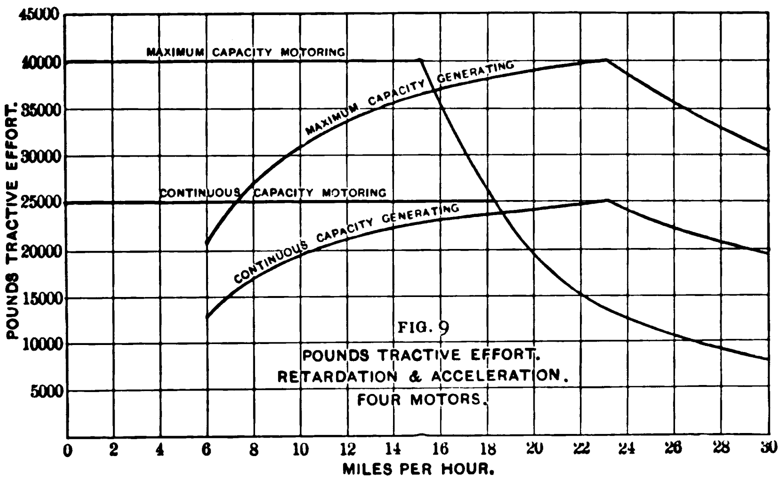

FIG. 9
POUNDS TRACTIVE EFFORT.
RETARDATION & ACCELERATION.
FOUR MOTORS.

tions it could not be made to exceed one half of this, while under unfavorable conditions or with a level track and long runs, using the regenerative function only for braking, the saving could not be more than a few per cent.

The value of this system of regeneration is not to be found so much in the saving of power as in the saving in wear and tear and the ability to operate over a wide range of speed, as well as the comparative safety of operation. In the case of running heavy trains down long grades, the braking apparatus of all cars in the train can be held in reserve, it being necessary to use it only in emergency or in making the final stop. Under these conditions the number of accidents due to the failure of the brakes would be very much reduced.

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This is the only system of regeneration yet developed which can be operated at maximum efficiency over a wide range of speed. In the case illustrated, forty speeds between 9 miles per hr. and 30 miles per hr. are obtained. This number can be increased if desired simply by the addition of a few switches.

The three-phase system is the only other one in which the regenerative function has been developed to any extent, but at most there are only a few widely separated speeds at which it can be operated efficiently. Generally there is but one.

A system of electric traction in which the trains must go up-grade and down-grade at one fixed speed in order to operate efficiently is certainly at a disadvantage when compared with one in which the trains can be operated at *any* speed *below* a certain maximum speed up-grade and at *any* speed within safe limits down-grade, at all times, whether taking energy from the line or restoring it to the line, the apparatus operating with maximum efficiency.

It will be noted that in this system the impressed voltage is changed to adapt it to the generated voltage, while in the direct-current or the three-phase system there is but one impressed voltage available.

This wide range of working voltage, with the ability to vary the armature current with respect to the field through a wide range, gives to the single-phase series motor the extreme flexibility as a regenerator of power that it has as a motor.

One other point that is worthy of note in connection with the operation of this system is the absolute safety and stability of the combination. While the machines being operated as generators are normally series machines, it will be noted that no one of the armatures is connected in series with its own field, and under no condition can there be any surging or building up of load. In case of momentary interruption of the supply circuit, the circuit again being restored the system will again operate exactly as before the interruption, there being no surging or violent action of the machines.

The system of regenerating power here described has been used in testing locomotives to give a dead-load condition under a wide range of speed.

Numerous stand-tests have also been made, so that the operation of the motors under the conditions is well established and there is no doubt about the scheme doing all that is claimed for it.

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FRACTIONAL PITCH WINDINGS FOR INDUCTION MOTORS

BY C. A. ADAMS, W. K. CABOT, AND G. Æ. IRVING, JR.

For several years past some of our large manufacturers have used fractional pitch windings, for induction motors to a considerable extent, and for alternators to a lesser extent.

It was the original purpose of this investigation to develop by theory and experiment a method by means of which the effects of such windings may be calculated; and although this purpose has been successfully carried out as far as time allowed, there is still a very interesting part of the subject which must be left for another time; namely, the relation of fractional pitch windings to squirrel-cage motors.

THEORY

The theoretically ideal induction motor would have a very large number of symmetrically placed phase windings of full pitch on both primary and secondary structures, the primary windings being supplied with the same number of equal, symmetrical, simple harmonic electromotive forces. In this case the flux density across the air-gap, the primary current, and the secondary current would be distributed sinusoidally around the gap periphery at any instant, and these distributions would revolve smoothly around the periphery at synchronous velocity.

The chief difference between this ideal machine and the actual is that the number of phases in the latter is small and there must, therefore, be several adjacent conductors or slots carrying the same current at the same instant, thus forming what may be termed a *belt* of conductors in which the current increases and decreases as a unit. On either side of this belt is another, the current in which differs in phase from that in the first by a considerable angle, 60° in a three-phase and 90° in a two-phase

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motor. Thus the current varies from point to point around the periphery by jumps or steps rather than gradually, as in the ideal motor.

It is a well known fact which has been demonstrated both theoretically and experimentally that even an ordinary induction motor, if it have a low-resistance squirrel-cage secondary, and be supplied with simple harmonic electromotive forces, will have a gap flux whose peripheral distribution is approximately sinusoidal at each instant, the effect of the slot openings being neglected.

Even in the case of a phase-wound secondary, the most satisfactory common ground for calculation is the assumption of a sinusoidal peripheral flux distribution, for although it may be claimed that such a distribution does not exist in fact, the results of calculations based upon this assumption are sufficiently close to the observed facts to render its use quite warrantable.

Differential factor. When an harmonically distributed flux sweeps round the gap periphery it causes to be induced in the conductors of any given slot a simple harmonic electromotive force. If this slot is one of three per pole per phase of a three-phase motor, there will be induced in the conductors of these three slots of the same phase, three harmonic electromotive forces differing in phase by 20°, and these three electromotive forces will add together vectorially to form a resultant whose magnitude is about 0.96 of their numerical sum. This slight loss of effectiveness in electromotive force generation, which is due to the fact that different conductors of the same phase belt are at certain periods experiencing electromotive forces of opposite sign, may be termed *differential action*, since it consists in the differential cutting of flux by conductors of the same phase belt. Similarly the factor (0.96 in this case) by which the total numerical electromotive force must be multiplied to obtain the actual resultant electromotive force, may be called the ***differential factor***. But differential action in these phase belts is not confined to electromotive force generation; it also appears in a similar manner in the production of an harmonically distributed magnetomotive force by currents in these belts. This means that a larger current per phase is required to produce a given magnetomotive force than in the ideal motor. If the secondary is supplied with an ordinary phase winding, the belts of this winding will be subject to the same differential action, both in the generation of electromotive force and in the production of

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torque by the reaction of the current belts on the gap flux. Moreover, in this latter case the overlapping of a secondary phase belt by parts of two primary phase belts, (or vice versa), results in local fluxes crossing the gap, which have components in phase with both primary and secondary currents and thus give rise to quadrature electromotive forces* which may be

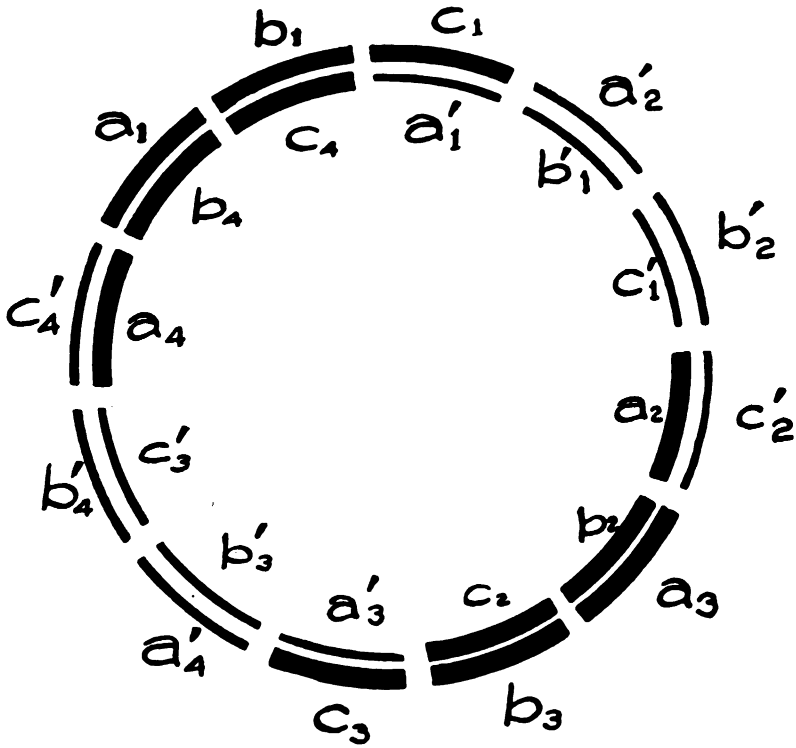

Fig. 1.

considered as another aspect of the belt effect or differential action.

The phenomena introduced by fractional pitch windings are largely of this same type, and may in most cases be treated as an

*This subject has been treated by one of the writers under the head of *Belt leakage*. Proceedings International Electrical Congress, St. Louis, 1904, Vol. I, page 706.

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extension of differential action. Thus if coils having a *pitch* or *throw* of less than 180° (electrical) be used for the winding of an induction motor, the effect will be to shift one of the layers of the winding around through a certain angle from its full pitch position, see Fig. 1, where a four-pole, three-phase winding with a two-thirds pitch is shown diagrammatically. The positive or backward connected belts are shown in heavy lines, and the negative or outward connected belts in light lines; the two sides of each phase coil are similarly lettered and numbered. The overlapping of currents of different phase in the same slots is here quite apparent.

Slot leakage. The reactance due to that part of the leakage flux which crosses a slot, linking with more or less of the conductors in that slot, may be expressed as follows:

$$x_s = 2\pi\, n\, \phi_s\, N^2_{cs}\, l\, \frac{N_t}{p'}\, 10^{-8} \qquad (1)$$

where n is the frequency, ϕ_s the flux per ampere per unit length of slot, N_{cs} the conductors per slot, l the length of the core, N_t the total number of slots, and p' the number of phases. None of these quantities is affected by a change of coil-pitch, except ϕ_s. This change will therefore be a measure of the effect produced upon the slot leakage by the fractional pitch.

Designate by θ the pitch of the coils in electrical degrees, and by β the angle of pitch deficiency $= 180°-\theta$. Then if the machine in question has a very large number of phases, the two coil-sides located in any given slot will in general carry currents which differ in phase by β degrees, and the component of one of these currents in phase with the other will be proportional to $\cos\beta$. If the product of the inductances of these two coil-sides is equal to the square of their mutual inductance, *i.e.* if there be no relative leakage flux between them, the ratio of the average leakage flux linked with one, to what it would be with full pitch winding and no phase difference between the two currents, is $\frac{1+\cos\beta}{2} = \cos^2\frac{\beta}{2} = \sin^2\frac{\theta}{2} = k_p$. This may be called the slot-pitch factor, under the two above mentioned conditions. But neither of these conditions exists in practice.

Consider first the relative leakage between the two coil-sides in the same slot. Referring to Fig. 2, the flux linked with coil b per inch length of slot for one ampere in b is

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$$\phi_{bb} = \frac{3.2}{w}\left(\frac{d_1}{6} + \frac{d_1}{2} + d_2\right)$$

The flux linked with b per inch of slot for one ampere in a is

$$\phi_{ab} = \frac{3.2}{w}\left(\frac{d_1}{4} + d_2\right)$$

But the current in a differs in phase from that in b by an angle β, and the component of ϕ_{ab} in phase with ϕ_{bb} is $\phi_{ab}\cos\beta$. Then the total in-phase flux linked with b per slot inch and for one

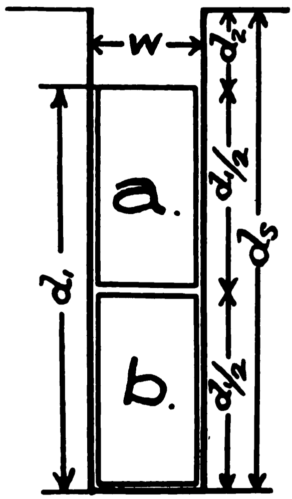

Fig. 2.

ampere distributed uniformly over the whole copper section of the slot, is,

$$\phi_b = \frac{\phi_{bb} + \phi_{ab}\cos\beta}{2} = \frac{3.2}{w}\left[\left(\frac{d_1}{3} + \frac{d_2}{2}\right) + \cos\beta\left(\frac{d_1}{8} + \frac{d_2}{2}\right)\right]$$

Similarly

$$\phi_{aa} = \frac{3.2}{w}\left(\frac{d_1}{6} + d_2\right)$$

$$\phi_{ba} = \frac{3.2}{w}\left(\frac{d_1}{4} + d_2\right)$$

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$$\text{and } \phi_a = \frac{\phi_{aa}+\phi_{ba}\cos\beta}{2} = \frac{3.2}{w}\left[\left(\frac{5}{24}d_1 + \frac{d_2}{2}\right)+\cos\beta\left(\frac{d_1}{8}+\frac{d_2}{2}\right)\right]$$

Then since each coil has one side in the bottom and the other in the top of a slot, the average flux linkage per ampere inch of slot will be

$$\phi_s = \frac{\phi_a+\phi_b}{2} = \frac{3.2}{w}\left[\frac{d_1}{12}+\left(\frac{d_1}{4}+d_2\right)\left(\frac{1+\cos\beta}{2}\right)\right] \tag{2}$$

or

$$\phi_s = .267\frac{d_1}{w}+\frac{3.2}{w}\left[\frac{d_1}{4}+d_2\right]\sin^2\frac{\theta}{2}.$$

There is thus a small portion $\left(0.267\frac{d_1}{w}\right)$ of the slot leakage which is independent of the coil-pitch; it is obviously that part which lies between the two coils, and would disappear if the latter were placed side by side in the slot rather than one on top of the other.

With this correction, the slot pitch-factor becomes

$$k_p = \frac{\frac{d_1}{12}+\left(\frac{d_1}{4}+d_2\right)\left(\frac{1+\cos\beta}{2}\right)}{\frac{d_1}{12}+\left(\frac{d_1}{4}+d_2\right)} \tag{3}$$

If the slot is partly closed, the resulting increase in ϕ_s is common to both coils and would involve a change in only that part of formula (2) which is affected by the coil-pitch.

In Fig. 3, curve A gives the values of $\frac{1+\cos\beta}{2}$ corresponding to different values of the coil-pitch, and curve B gives the corresponding values of k_p from equation (3), for a motor with open slots, in which the coils occupy about 80% of the slot depth. If the slots be partly or wholly closed, the constant part of equation (2) decreases relatively and the corresponding k_p curve will drop down, approaching more nearly to curve A.

In all this a very large number of phases has been assumed. Consider now the effect of a small number of phases. Take for example a two-phase motor with $\frac{3}{4}$ pitch. $\beta = 45°$ and k_p taken from curve B, Fig. 3, is 0.88. The two layers of the winding will be as in Fig. 4, where the relative phases of the currents in the several belts are indicated. Consider the 0° belt

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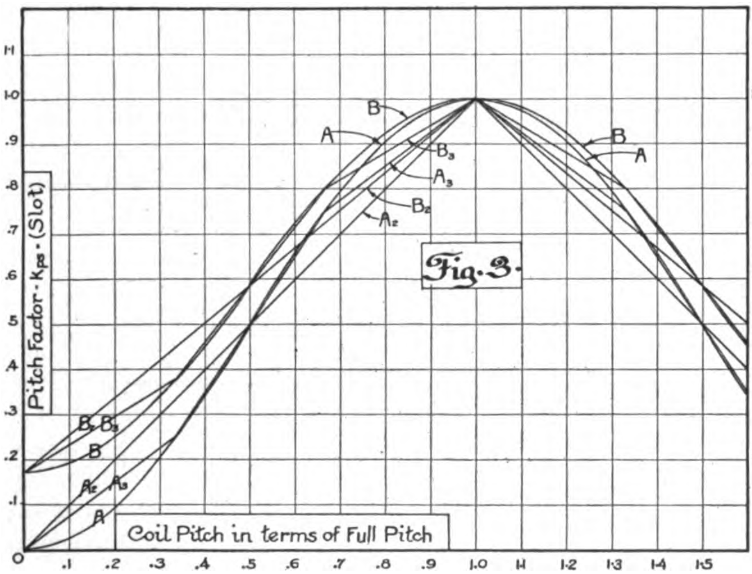
in the upper layer; half of it overlaps a 0° belt in the lower layer and the pitch-factor for this half is therefore 1; the other half overlaps a 90° belt in the lower layer, with a corresponding pitch-factor of 0.585. Thus the average pitch-factor for the belt is 0.792 in place of 0.88 as given by curve *B* or equation (3).

If the coil-pitch is deficient by one or more whole belts, the conditions will be exactly the same as those for which the curve *B* Fig. 3, was calculated. Therefore that curve will give the correct pitch-factor of a three-phase motor for a ⅓ and for a ⅔ pitch, and of a two-phase motor for a ½ pitch winding.

A little consideration will show that between these points the actual pitch-factor will follow a straight-line law.



In Fig. 3 the lines B_2 and B_3 show the variation in k_p for two and three-phase motors respectively. A_2 and A_3 show the same factors when the relative leakage between the two coil-sides in the same slot is neglected.

Tooth-tip or "zigzag" leakage. The expression for the tooth-tip leakage reactance is of the same form as that for the slot leakage;

$$x_{tt} = 2\pi\, n\, \phi_{tt}\, N^2_{sc}\, l\, \frac{N_t}{p^1}\, 10^{-8} \tag{4}$$

where ϕ_{tt} is the tooth-tip flux per ampere inch of slot, for both primary and secondary.

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As far as the fractional pitch effect is concerned, this element is exactly on a par with that part of the slot leakage which crosses the slot above the conductors, since it is wholly common to both coil-sides. The *tooth-tip pitch-factor* will therefore be that shown by lines A_2 and A_5 Fig. 3.

Coil-end leakage. The coil-end reactance may be expressed as follows:

$$x_f = 2\pi\, n\, \phi_f\, p \left(\frac{N}{2p}\right)^2 l_c\, 10^{-8} = \frac{2\pi}{4}\, n\, \phi_f\, \frac{N^2}{p}\, l_c \qquad (5)$$

where ϕ_f is the flux per ampere inch of the whole phase belt bundle of coil ends, p the number of pairs of poles, N the con-

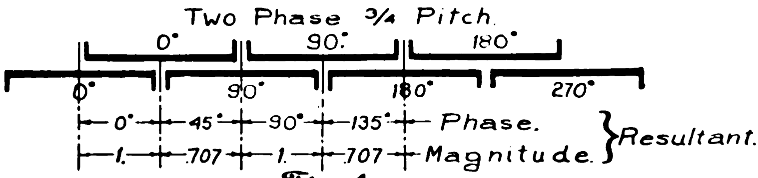

Fig. 4.

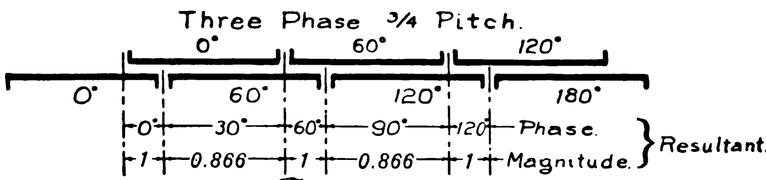

Fig. 4a.

ductors per phase and l_c the length of the two ends of one coil, usually about three times the coil-pitch. There are two terms in equation (5) which vary with the coil-pitch, l_c in a comparatively simple manner, and ϕ_f in a manner not so obvious.

For a circular coil in air, ϕ_f, the flux linked with one inch of the coil as a whole, per ampere distributed uniformly throughout the section of the coil, is proportional to the logarithm of the ratio of coil diameter to the diagonal of its cross-section, provided this ratio is large. For coils such as are used on induction motors this relation holds only in a general way, especially when the mutual inductive effect of neighboring coils is taken account of, and when the pitch is fractional. However, within

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practical limits ϕ_f would increase in approximate logarithmic relation to the coil-pitch, were it not for the mutual inductive effect of adjacent phases, and the curve representing this relation would tend toward a zero which is not that of the pitch.

Consider now the mutual inductive effect of adjacent phases. For pitches less than unity, this decreases in about the same ratio as the self-inductive effect and thus does not much change the general shape of the curve. But for values of the pitch greater than unity, the mutual inductive effect of opposing phases begins to count and to reduce considerably the otherwise value of ϕ_f. Thus the curve showing the relation between ϕ_f and the coil-pitch should be logarithmic in its general character, tending toward zero at some small (not zero) pitch, and falling increasingly below the logarithmic curve for pitches greater than unity. This, in fact, is approximately the shape found by experiment.

Belt leakage. The belt reactance may be expressed:

$$x_b = 2\pi\, n\, \phi_b\; 2\, p \left(\frac{N}{2p}\right)^2 l\, 10^{-8} = \pi\, n\, \phi_b \frac{N^2}{p}\, l \qquad (6)$$

where ϕ_b, the flux per ampere inch of the belt, is inversely as the reluctance of the belt magnetic circuit, and proportional to the sin² of ½ the angle of phase difference between the currents in the two opposing belts. ϕ_b is thus proportional to the belt-pitch and inversely to the air-gap.*

In the analysis of the effect of fractional pitch upon belt leakage, each case is a law unto itself, and requires a special quantitative analysis, which is not always short. The results, however, are in some cases most interesting, and can best be considered in conjunction with the experimental data.

Exciting reactance. In the case of fractional pitch, a higher flux density is required in the gap in order to produce the same resultant electromotive force, because the electromotive forces in the two sides of any given coil differ in phase by β degrees. The electromotive force differential-factor is then $\cos\frac{\beta}{2}$ or $\sin\frac{\theta}{2}$ where θ is the coil-pitch angle.

Not only is the exciting current higher because of the increased gap density, but it is still further increased because of the overlapping of currents of differing phase and the consequent reduction

*See the paper referred to in note at bottom of third page of this paper.

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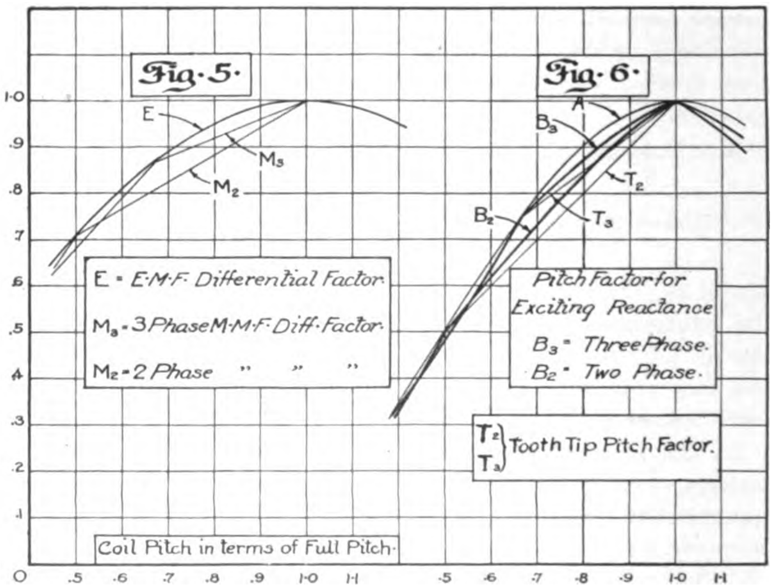
in effectiveness for magnetomotive force production. The magnetomotive force differential factor is cos $\beta/2$ only when the coil-pitch is an exact multiple of the belt-pitch. For example, take the two-phase motor with 0.75 coil-pitch, Fig. 4, the average of the resultant currents is $\frac{1.707}{2} = 0.853$, but cos $\frac{\beta}{2} = 0.96$. In Fig. 5, curve E shows the electromotive force differential-factor, M_3 the three-phase and M_2 the two-phase magnetomotive force differential-factor. The pitch-factor for the exciting reactance is then the product of E and M_2 or of E and M_3 and is shown in curves B_2 and B_3 of Fig. 6.



Results of Experiments

The motor tested had 48 slots, (see Fig. 7) on stator and rotor and several sets of coils were used in the same core. Short-circuit tests were made at 300 and at 60 cycles, and open-circuit tests at 60 cycles. The latter were made with rotor stationary. Each set of coils had the same number of conductors per slot, as had the rotor and stator coils.

Coil-end reactance. The core was removed except for two plates, just sufficient to support a set of short coils. Short-circuit tests with this arrangement were practically useless owing to the relatively large exciting current; so the

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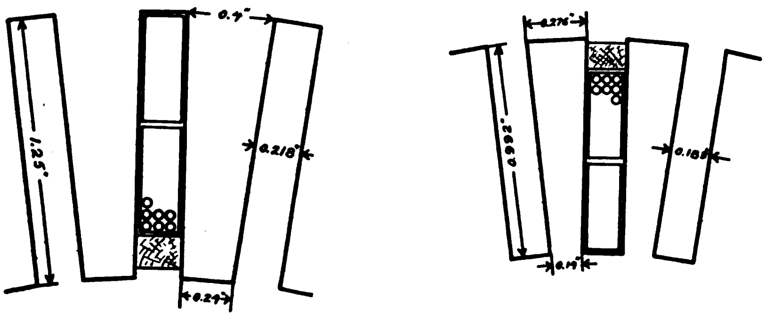
primary and secondary were connected in series, phase for phase, and the opposing belts set opposite each other. Then, since there were the same number of turns in primary and secondary, no flux crossed the gap, and the total impedance was accurately determined. Moreover, by measuring the drop across primary and secondary, the two impedances were separated. The very small slot reactance due to the two core discs was then computed and subtracted from the total, leaving the coil-end reactance alone.

Two sets of coils were employed in these tests. One set with a pitch of twelve slots was connected for three phases; two poles and four poles; half and full pitch respectively; both primary and secondary being connected in exactly the same manner.

Fig. 7.



Stator — 48 Slots

Rotor — 48 Slots

The other set with a pitch of nine slots was connected for three phases; two poles, four poles, six poles, and eight poles; $\frac{3}{8}$ pitch, $\frac{3}{4}$ pitch, $1\frac{1}{8}$ pitch, and $1\frac{1}{2}$ pitch respectively; making in all six combinations with the short coils.

From the reactances obtained from these tests, the corresponding values of ϕ_f were computed by means of equation (5), in which l_c was taken as the total length for both primary and secondary. The results were plotted in the curves of Fig. 8. The difference between ϕ_f for the twelve-slot coils and the nine-slot coils is due to the fact that in the latter case the primary and secondary coil ends were bent farther back, thus leaving more room for leakage between them.

The upper curve of Fig. 8, shows both sets brought together

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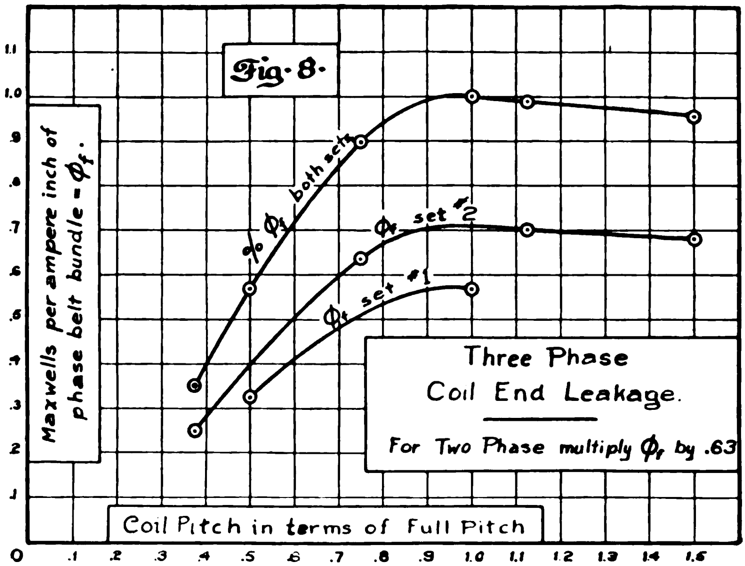
by plotting each set in terms of its full pitch value. The curve of Fig. 9 shows the total coil-end pitch-factor for a special case where l_c is taken equal to 5 in. $+ 2.8\lambda_c$, λ_c being the coil-pitch in inches. The pole-pitch was taken as 10 in.

The coil-end pitch-factor is then:

$$k_{pc} = (\phi_f \text{ in terms of that for full pitch}) \times \frac{5 + 2.8\lambda_c}{5 + 2.8\,\lambda_p}$$

If all the coil-end leakage be charged to the primary, the corresponding full pitch value of ϕ_f for the first set of tests is 1.14, and 1.35 for the second set. The first of these corresponds more nearly to a normal induction motor.



For a squirrel-cage motor with bars extending well out from the core, the value of ϕ_f (all charged to primary) is known to be about one or a little more, which is very close to the value given above for a wound rotor. No experiments of this sort were made in the present investigation; but many instances are at hand where a considerable change has been made in the reactance of a squirrel-cage motor by altering the disposition of the end-rings. The writer hopes to investigate this matter in the not distant future.

Slot reactance. Following the above described coreless tests, the normal core of length l = 3.2 in. was replaced and tests were

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made with two different sets of coils; one set having a coil pitch of twelve slots and the other nine slots. The first set was connected in four combinations, two-phase two-poles; two-phase four-poles; three-phase two-poles; and three-phase four-poles; the second set was connected in five combinations, two-phase four-poles; three-phase, two-poles, four-poles, six-poles, and eight-poles. In the second set the wires were placed in the slots without taping and were depressed as much as possible, see Fig. 10.

Series tests were first made with the secondary belts directly opposite the corresponding primary belts, thus eliminating both tooth-tip and belt reactance.

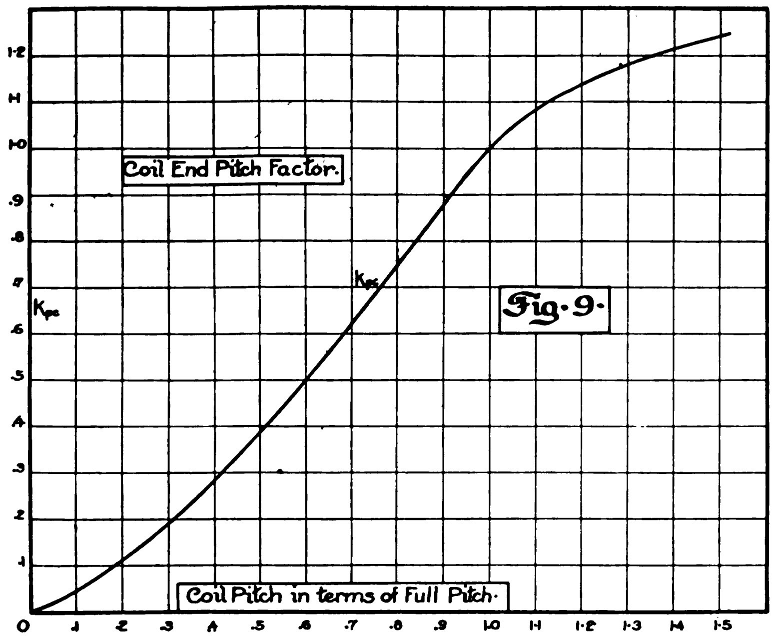

Fig. 9.

Ordinary short-circuit tests were then made, (*a*) with belt opposite belt as in the series test, (*b*), one half of the tooth-pitch beyond position "*a*", where the tooth-tip leakage is a maximum, and (*c*) one half belt beyond position "*a*" where the belt leakage is a maximum.

Tests were then made with the secondary open circuited to determine the exciting reactance.

The short-circuit tests "*a*" gave reactances uniformly two or three per cent. lower than the series tests, as was to be expected.

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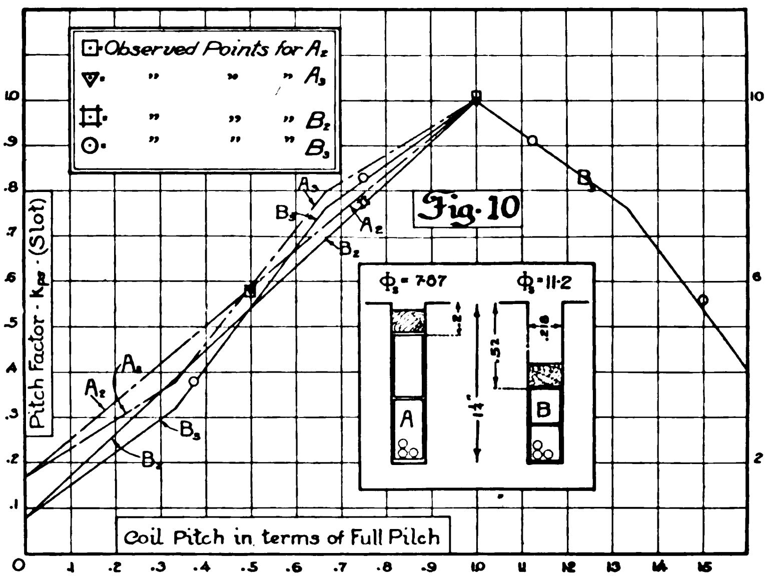
From the reactances obtained from the series tests, the coil-end reactances, (as calculated with the aid of the coreless tests) were then subtracted. The remainders are the slot reactances. The full pitch values of ϕ_f used in calculating x_f were 0.66 for the first set, (the twelve-slot pitch coils), and 0.70 for the second set, (the nine slot pitch coils). In both these cases, the coil-ends were bent well back in order to make room for the temporary between-coil connections which had to be changed several times. At first 0.70 was chosen for both sets, but it was found that 0.66 gave more consistent results for the slot leakage in the first set. This is also what might have been expected since, in



the second set, the primary and secondary coil-ends are farther apart where they come out of the slots.

From the slot reactances obtained above, ϕ_s was calculated from equation (1). The slot pitch-factor is then $k_{ps} = \phi_s \div \phi_{s1}$ where ϕ_{s1} is the value of ϕ_s for full pitch.

The values of k_{ps} thus determined are plotted in Fig. 10 where the calculated curves from Fig. 3 are also shown. It will be noted that the deviations of the observed points from the calculated curves to which they belong, are within the reasonable errors of observation and calculation, particularly when it is remembered that owing to the comparatively large values of x_f, which were

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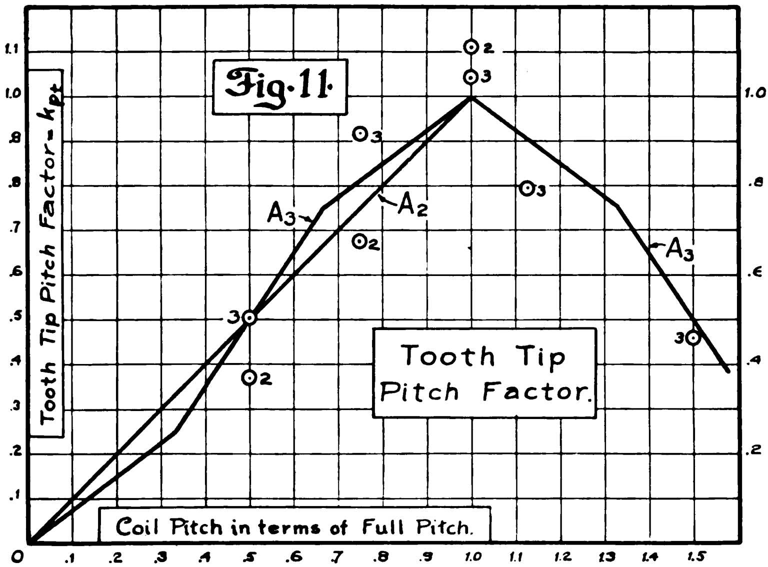
subtracted from the series test reactance x to get x_s the slot reactance, a moderate change in ϕ_f will shift the relative values of k_{ps} so that when plotted they appear to have little relation to the theoretical curves.

Tooth-tip or "zigzag" leakage. The difference between the "b" and the "a" reactances gives the maximum tooth-tip reactance x_{tt}, but it gives in addition a small portion of the belt reactance.

From this difference, ϕ_{tt} may be calculated by equation (4) and thence the tooth-tip pitch-factor. The results are plotted in Fig. 11, together with the theoretical curves A_2 and A_3 for two- and three-phase respectively, taken from Fig. 3.



These results may seem rather wild, but there are several reasons therefor. First, the tooth-tip leakage is, in this case, a comparatively small part of the total reactance, and a small error in either the "a" or the "b" reactance makes a large percentage error in their difference; secondly, it is not likely that the rotor was set each time in exactly the position of maximum tooth-tip reactance, since the maximum is a narrow one owing to the open slots on both sides of the gap; thirdly, because of the inevitable presence of the uncertain and variable amount of belt leakage mentioned above. Taking these things into account, the results are in very fair accord with the

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theory. There is every reason to believe that this element of the leakage follows the theory outlined, quite as closely as does the slot leakage.

Belt leakage. The maximum belt reactance was obtained from the short-circuit tests by subtracting the "*a*" reactance from the "*c*" reactance. The experimental results are given in Table I, and a few typical cases will be considered. In column x_{B_3} the two-phase belt reactances are reduced to two-thirds of their actual values for comparison with the three-phase reactances.

TABLE I

			No.	Pitch.	x_B	x_{B_3}
12-slot pitch	2 phase	2 poles	1	0.5	11.32	7.52
		4 poles	2	1.	6.02	4.01
	3 phase	2 poles	3	0.5	1.38	1.38
		4 poles	4	1.	0.846	0.846
9-slot pitch	2 phase	4 poles	5	0.75	0.81	0.54
	3 phase	2 poles	6	0.375	0.535	0.535
		4 poles	7	0.75	0.24	0.24
		6 poles	8	1.125	......	......
		8 poles	9	1.5	0.175	0.175

First compare the two-phase and three-phase belt reactances; No. 1 and No. 3 are alike in all other respects, but the two-phase is nearly 5.5 times the three-phase value; similarly with No. 2 and No. 4. The theoretical ratio of two to three phase is 5.1 for the same number of slots per belt; when the above results are corrected on this latter score, they compare still more favorably with the theoretical ratio.

Compare No. 1 and No. 2, the only difference between which is the number of poles and the fractional pitch. In No. 1 ϕ_b* is twice as great because of the increased belt pitch and p is one half; therefore x_b should be four times as great were it not for the pitch-factor which is thus, 0.53, about the same as for the slots.

*See equation (6.)

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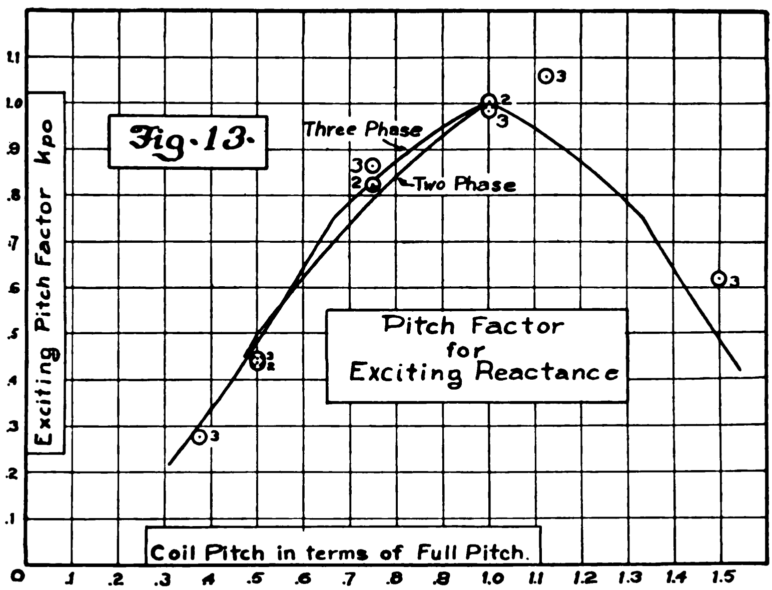
Compare No. 2 with No. 5, the only difference being in the coil-pitch. The reason for the great reduction will appear from an inspection of Fig. 4, which represents the two layers of the $\frac{3}{4}$ pitch winding of No. 5. The effect of the overlapping of the two layers is to double the number of resultant belts and to decrease the phase difference between them to one-half. There is still an unbalancing of the magnetomotive forces due to the different magnitudes of the resultants, but this cannot be analyzed by means of equation (6).

Comparing No. 5 and No. 7, which differ only in phase, we find no such contrast as between No. 1 and No. 3. The reason



for this will appear from the belt diagram of No. 7 shown in Fig. 4*a*; namely, that the maximum belt width is here reduced to only $\frac{2}{3}$ of its original value, whereas in No. 5 it was reduced to one-half. In fact, the maximum belt width is the same in No. 5 and No. 7, although they are two and three-phase respectively.

The result of this analysis is to show that the fractional pitch effect on belt leakage is largely dependent upon the relation between the coil-pitch deficiency and the belt-pitch, and that a proper choice of this relation makes a relatively very large reduction in the belt leakage, especially in a two-phase motor.

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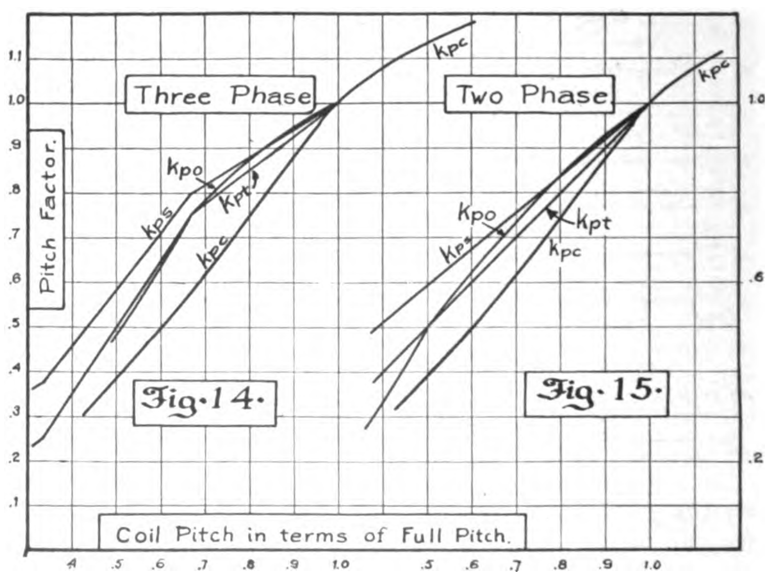
Such a choice also smoothes out the large kinks of the current distribution, and has much the effect of doubling the number of phases.

Exciting reactance. The exciting reactance was determined from the open-circuit tests made with rotor standing in the position of maximum reactance, namely, with the rotor teeth opposite the stator teeth.

In order to make the results comparable and thus be able to determine the pitch-factor, the exciting reactances were all reduced to a three-phase two-pole basis by multiplying by $\frac{p' p^2}{3}$. In addition to this, the two-phase reactances were multiplied by 1.10 in order to eliminate the difference between



the differential-factors of the two and the three-phase motors at full pitch.

In Fig. 13, the observed values of the pitch-factor for the exciting reactance are plotted together with the theoretical curves. No satisfactory explanation has been offered for the considerable deviation of the two high points on the right of the figure.

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Summary

All the principal pitch-factor curves for the three-phase motor are assembled in Fig. 14, and those for the two-phase motor in Fig. 15.

To sum up, the effects of a fractional pitch winding are:

a. A reduction of the several components of the leakage reactance.

b. A reduction of over-all length of the motor.

c. In some cases, a considerable gain in the convenience of winding as well as a saving of space.

d. A decrease in the exciting reactance; that is, higher densities in all parts of the magnetic circuit and a higher exciting current for the same voltage.

It will be observed that except for the reduction in endwise length over windings, the effect of fractional pitch is the same as that produced by reducing the number of active conductors, but although the latter method is in many cases the more efficient from the standpoint of operation, the former is frequently more convenient from the standpoint of the manufacturer, even when the saving in endwise length is not a controlling factor.

There are, however, cases of high-speed motors where the fractional pitch winding is more efficient from every standpoint than the full pitch winding of fewer turns.

As an example of a fractional-pitch problem, consider a three-speed, three-phase induction motor. The comparative constants for the three speeds are given in the following table:

Poles.	rev. per min.	Relative gap density	Relative core density.	Relative exciting current.	Relative reactance.	Relative safe output	Power-factor
4	1800	0.77	115	59	95	103	0.93
6	1200	100	100	100	100	100	0.90
8	900	154	115	237	75	84	0.76

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A paper presented at the 24th Annual Convention of the American Institute of Electrical Engineers, Niagara Falls, N. Y., June 28, 1907.

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COMMUTATING-POLE DIRECT-CURRENT RAILWAY MOTORS

BY E. H. ANDERSON

General. In order to appreciate the development and reasons for the existence of a commutating-pole railway motor, it is well to discuss in some degree some other developments. In the beginning, railway-motor designers had many difficulties to contend with.

1. The question of gearing was possibly foremost, whether it should be single or double reduction or possibly gearless. All these were tried with more or less success. The pendulum swung back and forth from this point, but it has settled partly and is still settling. The small motor (automobile) is now more usually double reduction; however, in some cases, single reduction is used where weight is not of importance. The usual railway motor has settled down to single reduction. In the larger railway motor, where the work approaches that of a locomotive, it is often questionable whether single reduction or gearless should be used. When powers are small, as in the case of single-car units, the motor is naturally provided with single-reduction gearing. Then again, for large locomotives and high speeds, obviously the motor should be of gearless construction, this being especially true in the light of what may be done with gearless bipolar motors of direct-current design.

2. Possibly, insulation is next in order, various methods having been tried. The conductors have been covered with a variety of materials, but double or triple cotton-covered insulation has practically become standard. The slot insulation has been through various changes; for wire-wound machines it has settled down to a good varnished cambric with a protecting tape

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of cotton, although an all-asbestos insulation of armature coils is promising.

Where bars are used as armature conductors, it is possible to insulate them entirely with mica. This type of insulation has been fully developed and may be considered as standard.

The field insulation has long been in a state of evolution, but is pretty well standardized on a basis of mica in metallic shells for the larger ribbon-wound field-coils, and varnished cambric for the smaller fields wound with wire. Here also an all-asbestos insulation is promising.

3. The present method of lubricating the bearings with oil has resulted from a process of elimination; many forms of grease-cups, oil-cups, wicks, etc., having been tried; in fact, the preferred lubrication at one time was grease.

With the advent of interurban trolley roads came greater speeds, giving rise to many more car-miles per day, and complaints arose of short life of bearings, injury to armatures, etc. The methods of lubrication underwent many changes, but are now well established as wool-waste and oil; no doubt a good solution of a difficult and important problem.

4. During this period of development, the armature was changed from a smooth to a slotted core, and much thought was given to the size of commutator, number of segments, turns per coil, etc., in the effort to produce successful operation of the commutator.

With all forms of copper brushes there was most destructive sparking and enormous local currents in coils short-circuited by the brush during commutation.

The carbon brush was tried and found to be the greatest improvement yet discovered in producing successful commutation. The greater contact resistance decreased the local currents to reasonable values, yet the energy lost by the greater contact resistance in the main circuit was small. The carbon brush thus opened up possibilities in design not before thought of.

The inductance of coils was reduced by placing two in one slot instead of one, thus saving insulation and reducing the diameter of the armature. Later came the three coils per slot armature, this being the standard for many motors to-day.

As motors had to be built to fill a restricted space, not only for large power and small diameters, but with good commutation at higher potentials, it gave rise to the four and five coils per slot armature. Many coils per slot necessarily increased the slot-

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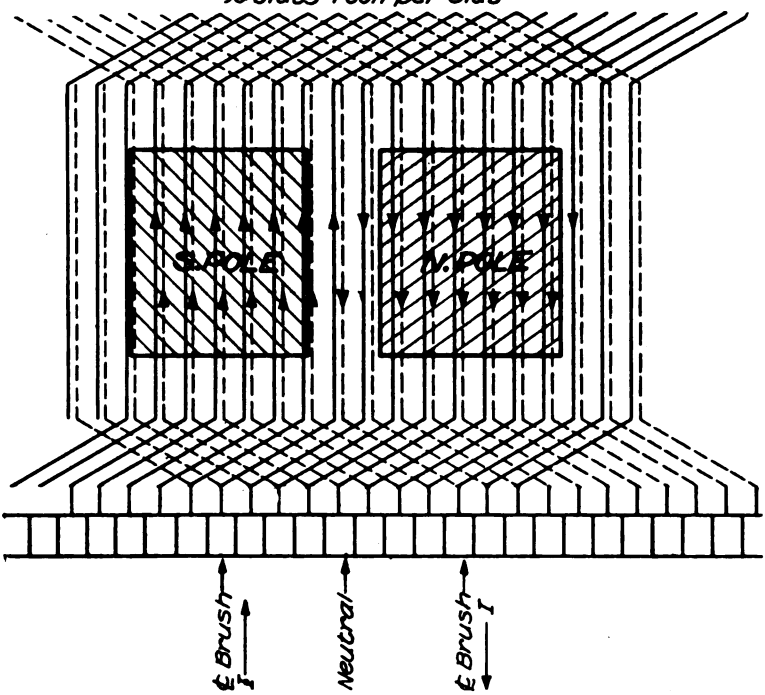
width, and this in time called for a laminated-field pole structure in order to limit eddy-current losses. In the meantime the operator was demanding higher potentials, more work from the motors, and better commutation, and the commutation had not kept pace with other developments, in fact, was becoming more troublesome as compared with other difficulties, largely on account of higher operating potentials. Some means had thus to be adopted for radically improving commutation, and the following pages deal more particularly with this subject.

Fig. No. 1 D.C. Series Drum Armature
33 Slats 1 Coil per Slat



Armature forces. The armature in its simplest conception is a drum, divided into four sections for four poles; under a north pole is a broad distributed sheet of current running parallel to the shaft; under a south pole is also a broad distributed sheet of current, but in reverse direction.

This distributed armature current produces a magnetizing force which changes the distribution of the main flux in the pole-faces, as shown in Fig. 2. It will be seen that in the

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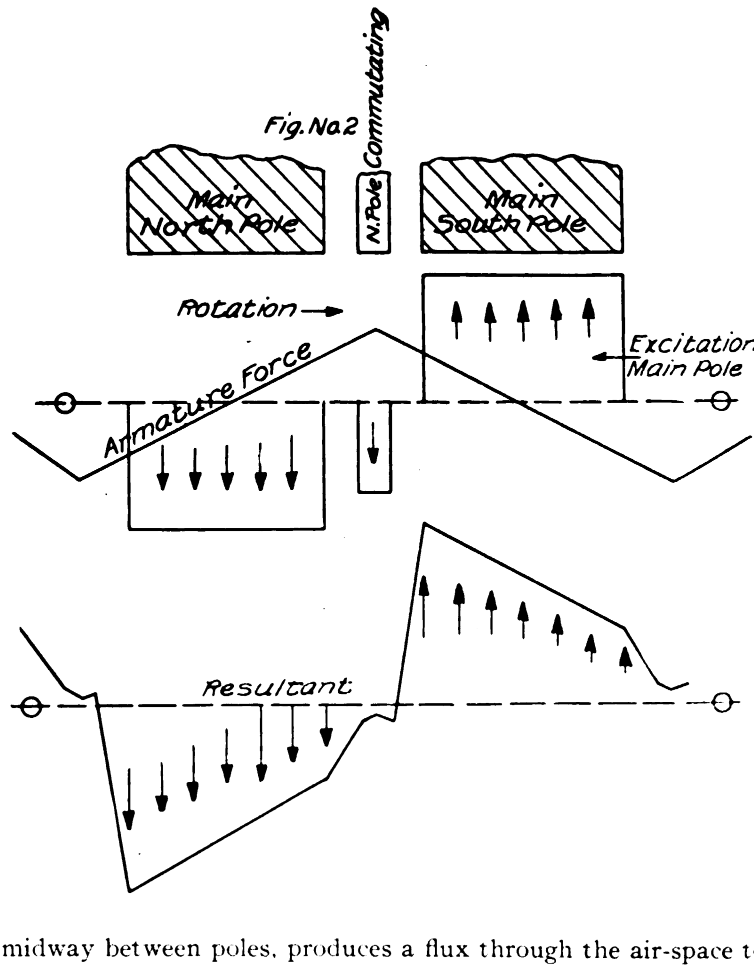
center of the pole there is no distributing effect, but in the center between poles there is the maximum magnetizing effect from the armature. This is where the conductors are commutated by the brush and the direction of the current reversed in passing from the zone of one pole to the zone of the next.

The magnetizing effect of the armature, being a maximum

Fig. No. 2



midway between poles, produces a flux through the air-space to the frame. The conductors in motion cut this flux, producing a voltage in the coil to be commutated.

The combined result of armature and field magnetizing effect is to cause a flux to leak from the pole-tip over into the armature just where the conductors are being commutated.

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The two leakage fluxes are alike and add to produce voltage in the coil which is being commutated. Thus there is a potential between commutator-bars, and when these are short-circuited by the brush a local current is caused to flow in the coil under commutation. This local current adds to the line current already there. Any conductor carrying current has lines of force interlinked about itself caused by the current in the conductor. The conductors, imbedded in and surrounded on three sides by iron, have a good opportunity of surrounding themselves with a lot of leakage flux. The interlinkage of leakage flux is similar to the inertia in mechanics.

The combined current (line and local) has still greater interlinkage of leakage lines and becomes more difficult to reverse. The reversing has been done heretofore by the increasing resistance of contact between the brush and the commutator-bar as the latter is passing out under the brush, the rate of change of current ever increasing. This causes the reactance or kicking voltage to become higher and higher. As the bar leaves the brush, the change in current in the coil becomes so rapid that an appreciable voltage is induced and arcs through the air from the bar to the brush, or vice versa, thus producing what is commonly known as sparking.

The object is, then, to remove the sparking by counteracting one, or all, of its causes. Should we place midway between the main poles another coil, having the same magnetizing power as the armature, but so connected as to magnetize in the reverse direction to the armature, there would be nothing to cause a leakage flux from the armature to the frame. Then, again, should we further excite this coil so as to overcome and balance the combined effect of armature and field forces, commonly known as distortion and leakage of the main flux from the pole-tip, we would annul this troublesome cause of sparking. After the above two effects are taken care of, there remains a force necessary to produce a potential sufficient to reverse the current in the armature coil.

In order to produce this potential there must be such a density of flux as will generate this required voltage by the conductors cutting the flux in revolving. The width of such magnetic density should be sufficient to embrace the conductors commutated by the brush when running in either direction of rotation.

The commutating voltage produced by the flux of the com-

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mutating pole is the accelerating force required to change the direction of current in the armature coils one by one as they come under the brush. It must be sufficient to accomplish this in the time that the coil, being connected to two adjacent commutator-bars, is under the brush. When the commutator-bar leaves the brush, the current is already reversed, flowing in proper direction, and is of the proper amount, so there is no tendency to spark. Commutation may then be said to be perfect.

As stated before, an armature coil imbedded in iron is surrounded by a leakage flux, which is caused by the current in the coil, and may be said to have magnetic inertia or momentum. This is similar in mechanics to a revolving shaft bearing a mounted flywheel. The voltage induced in the coil by the flux from the commutating pole may be likened to a constant counter torque; this counter torque serving to slow down the revolutions, stop, and cause an increase in speed in the opposite direction.

It is evident that there may be a particular armature current, speed of motor, and flux from commutating pole wherein the above described conditions will obtain. It will also be appreciated that the voltage induced by the commutating-pole flux will vary directly as the speed; furthermore, the time that the coil is under the brush is shorter as the speed is higher, and vice versa; also that the time required to reverse a current is inversely as the voltage. The conclusion is that the action is entirely automatic throughout the entire range of speed with the particular condition of current and commutating-pole density.

The next question is: can the action be automatic for varying current as well as speed? The commutating pole may be excited by the main current of the motor, being connected permanently in series with the armature. The commutating-pole flux will then vary almost directly as the current, which is the desired result. When the current is half, the commutating-pole flux is half, and the commutating voltage corresponding thereto. Thus the action is entirely automatic for variation in current or speed, or both.

Fig. 3 shows that the relation between commutating-pole density and current should be a straight line, rising and falling directly with the current.

It is well understood that an absolutely straight line be-

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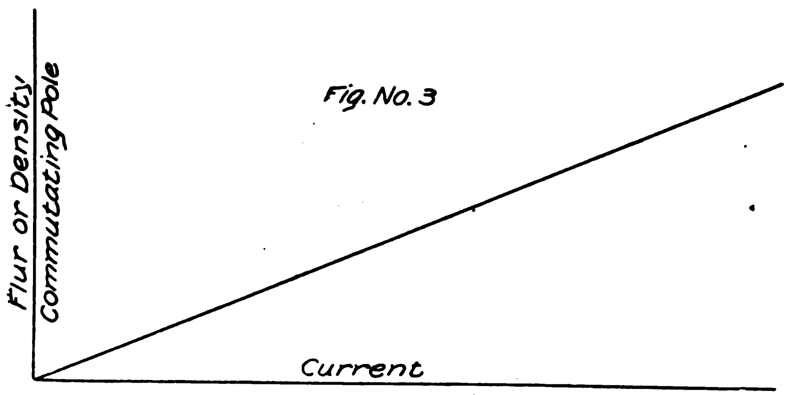
tween current and density cannot be obtained when a more or less saturated iron circuit carries the flux, but it can be approached sufficiently close for all practical purposes by careful design and experience in these matters. In a series motor the density of the whole iron circuit increases as the load comes on, and there is an increasing stability in commutation which serves to offset, partly, if not entirely, the lack of commutating-pole density on a heavy load. The combined effect is to produce perfect commutation at all loads.

Since the commutation is automatically taken care of for variations in speed and current, it is possible to change the voltage impressed on the motor through quite a range without sparking. This is thoroughly borne out by motors of 50 to 250 h.p., recently constructed in this country.



The only limitations in raising the voltage are:

1. Armature speed and strength of binding wire.
2. Volts between bars.
3. Insulation.

This brings us naturally to the question: what effect will this commutating pole have on designs for voltages higher than are now general for railway service?

Railway-motor commutators before being connected to the armature winding are tested from bar to bar with 400 to 500 volts, alternating current, which means a maximum of 40% more, so that actual jumping of current from bar to bar on a clean commutator would not occur at less than 500 volts per segment. An ordinary commutator of 111 segments and four

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poles would, under these conditions, be good for 13,000 volts between brushes. The actual jumping of current across side micas of a clean commutator is not the limiting condition.

The limiting condition is the voltage per bar which will maintain an arc already established. The allowable voltage per segment is largely dependent upon the condition of the commutator. The condition of the commutator depends upon the deteriorating tendencies, such as sparking and other causes, like poor carbon brushes, hard side micas, etc.

If the sparking is eliminated, the etching of the commutator-bars is largely reduced. The carbon brushes are required to carry only the line current, instead of the line and a large amount of local current; therefore the brushes are not disintegrated so rapidly. The carbon brush has less mica to wear off, because the bars are not burned away. The result is that the carbon brushes work better, and the commutator stays in a very much better condition. The conclusion from the above is that much higher average volts per segment may be used with commutating-pole motors than with motors not having commutating poles.

The usual non-commutating pole railway motor, 40 to 50 h.p., has a commutator about 9.5 in. in diameter, with 111 to 125 segments. The average potential between segments is approximately 18 volts. Large motors, operating on 650 volts normal, have 155 to 165 segments, and the average potential between segments is approximately 17 volts. If the average volts between segments on commutating-pole motors be assumed as 24, and the number of commutator bars per inch of circumference as 5, we have the following possible voltages on various sizes of motors and commutator diameters.

Horse power	Diameter of commutator	Maximum volts motor
40	9	850
75	11	1040
100	13	1230
150	14.5	1370
200	16	1510
250	18	1700

The above may be said to apply only as far as tendencies are concerned. Not all these various voltages would be practical. It would be better, for various reasons, to adopt 1200 volts as the higher standard.

The propositions requiring higher potential than 600 volts,

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are usually 30- to 50-ton cars with speeds of 40 to 60 miles per hr. These call for a motor of 75 h.p. or larger, so the sizes naturally fall where 1200 volts can be made with reasonable cost.

The commutating-pole motor, on 600 volts, makes possible commutation and general operation in service many times better than that of the non-commutating pole motor. On 1200 volts, the commutation is decidely better than with a non-commutating pole type motor on 600 volts.

The 1200-volt motor requires proportionally more insulation than the present 600-volt motor. This extra insulation requires more diameter and more external dimension.

Theoretical possibilities of voltage. We have the possibility of 1200 volts per motor, the motor having four poles. Should the motor be bipolar and the speeds high enough to make the design possible, we may have 2500 volts per motor. Then again, if there should be two windings on one core, a commutator on each, and these windings connected in series, we have the possibility of a 5000-volt motor. Then again, should we have a double-track railway and the rail neutral, we might have 10,000 volts direct current between the two trolley wires.

It will be appreciated that more voltage means more insulation, more space, and more cost. It will also be seen that the control, car lighting, and operation of auxiliary apparatus require special consideration.

Service capacity. The non-commutating pole motor has inherently a higher iron density, which serves as a compensating feature, improving commutation. The commutator-pole compensates for armature reaction and takes care of troubles due to lack of compensating features; a lower iron density may therefore be utilized and lower iron losses obtained.

The absence of sparking makes the commutating losses very much less. The rating on the hourly basis may not be much greater than with the non-commutating pole motor. On account of core-loss and commutator loss being considerably less, and these prominent features in heating, the commutating-pole motor has naturally a higher continuous rating; it is not only capable of taking large fluctuations of voltage and current, but will have a greater all-day service capacity. This latter feature becomes more pronounced as the distance between stops is greater.

There are several ways of making use of higher direct-current potentials. The most prominent of these are the following:

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1\. *a.* City service, 600-volt trolley.
Maximum speed 25 to 30 miles per hr.
Stops and schedules incident to city service.

b. Interurban service, 1200-volt trolley.
Maximum speed 50 to 60 miles per hr.
Few stops and high schedules.

The motors would be wound and insulated for 1200 volts.

Two motors would be connected in multiple, and the two groups of a four-motor equipment handled in series and in parallel.

2\. *a.* City service, 600-volt trolley.
Maximum speed 25 to 30 miles per hr.
Stops and schedules incident to city service.

b. Suburban service, 600-volt trolley,
Maximum speed of 30 to 60 miles per hr.
Stops and schedules incident to suburban business.

c. Interurban service, 1200-volt trolley,
Maximum speed 50 to 60 miles per hr.
Few stops and high schedule speed.

The motors would be wound for 600 volts with a relatively low armature speed and insulated for 1200 volts.

On a 600-volt trolley two motors are connected in multiple. and the two groups handled in series and parallel.

On a 1200-volt trolley, two motors are connected in series, and the two groups of four-motor equipment handled in series and parallel.

The armature speed and commutating features should be so designed that if one wheel slips and one motor has 1200 volts or so across its terminal, its armature speed will be reasonable and the commutation good.

Interurban cars with four axles and four motors usually accelerate at 1 to 1.5 miles per hr. per sec.; this requires about 100 to 150 lb. per ton, which is 5 to 7.5% coefficient of traction. These are low coefficient values for interurban roads and are seldom met with; however, should slipping occur, the motor design should be such that no damage to equipment will result. In the city a dirty street may give a low condition of traction, but under these conditions, the motors may be used in multiple or operated as any four-motor equipment is now operated.

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Advantages of Commutating-Pole Railway Motors as Compared with Non-Commutating Pole Type

1. Sparkless commutation even on heavy overloads.
2. Flashing at commutator largely reduced and probably eliminated.
3. Less wear on commutator.
4. Cleaner and safer motor because of reduced carbon and copper dust from brushes and commutator.
5. Marked reduction in heating of commutator.
6. Greater current density in brushes.
7. Increased life of brushes.
8. Increased efficiency and free running capacity because of lower core and commutator losses.
9. Possibility of successfully using higher voltages.
10. Greater facility in design of large motors, especially as regards commutation.
11. Possibility of increasing service capacity of motors by blowing.

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TRACK-CIRCUIT SIGNALING ON ELECTRIFIED ROADS.

BY L. FREDERIC HOWARD

Railroads signals may be divided into three general classes according to their functions: (*a*) Those which confer rights on trains, or restrict their rights, known as train-order signals; (*b*) Those which designate the route a train is to take, and insure the safe condition of all switches and opposing signals on such route, known as interlocking signals; (*c*) Those which are used primarily for properly spacing trains, known as block signals.

Originally the operation and control of all these classes was wholly manual. Owing to the fallibility of the human agency, however, and also on account of the greater scope of protection to be secured, means were gradually devised to take from the operator under certain conditions the power to clear signals, while permitting him at all times to restore them to, and retain them in, the stop position. In some cases the signals were taken from his control altogether and made automatic. Means were also devised to prevent the operation of any switch while a train was approaching or passing over it.

It will therefore be seen that there are three distinct types of signals according to method of control; namely, the manual or non-automatic, the controlled manual or semi-automatic, and the purely automatic. Train-order signals are of the first type, interlocking signals of the first and second types, while block signals are of all three types.

The track circuit is by far the best expedient for effecting the control of the signal operator, and the power-operated block signal. It is used largely in connection with the latter; and as a means for dispensing wholly with the human agency, and providing the safest and most practicable method of automatic

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control will, for some time to come, remain the essential part of the automatic signal system.

Beyond the track circuit are the various signals, switches, and other appliances, operated mechanically or by pneumatic or electric motors of various types. These are the parts used by the signal engineer in his art of increasing the capacity of a road for the safe handling of traffic over the miles of main line, and for safely accomplishing the maximum number of train movements in the least possible time, with the least cost for maintenance and operation in complicated yards and terminals.

The track circuit being the factor upon which the signal engineer primarily depends for the automatic control of his apparatus, the use of the rails on electrically operated roads as common conductors for both signal and propulsion currents has brought to the front new conditions and new apparatus in connection with the track circuit, with which it is advisable that the electrical engineer should become acquainted. In this paper I shall try to trace the development of track-circuit apparatus which has taken place in less than a decade, and give some idea of the relations existing between the track-circuit system and the propulsion system on electrified roads.

The track circuit, as it exists in its simplest form on steam roads, is shown in Fig. 1, except that the gravity cell is generally the source of electric energy. The storage-battery is rapidly coming into use for this service, however, and is shown in Fig. 1, better to illustrate the relations of the elements constituting the track circuit. These elements are: a source of electromotive force; a series resistance (comprised in the battery itself when the gravity cell is used); the rails forming the conductors, and insulated from the adjacent rails at the ends of the section, and in multiple across the rails the resistances of the relay, ballast, and ties. When the track section is occupied, there is another resistance in multiple with the foregoing; *i.e.*, that of the wheels and axles of the train.

Through the contacts of the relay are passed the circuits which control the apparatus governing admission to the section; as, for instance, the semaphore signal shown in the figure.

For convenience, the reciprocal of the resistances, or the conductances, of the ballast, ties, wheels, and axles will be used in much of what follows.

The circuit shown in Fig. 1 differs from those with which the electrical engineer ordinarily has to deal, in that it is operated

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by shunting, instead of disconnecting, the source of electric energy. This makes necessary the consideration of the relation of the operating shunt to the other elements of the circuit.

The " ballast conductance " (which is considered as including the conductance of the ties) is a variable, and for any given section its value depends upon the weather.

Suppose that the voltage across the terminals of the relay at which its contacts close is practically the same as that at which they open; or, as the signalman would say, that the " pickup point " is the same as the " shunting point". This supposition corresponds closely with the facts in the case of alternating-current relays, where motion may be considered as due to the reaction between currents, but is not true of the ordinary attracted armature direct-current relay where the shunting point is approximately one-half the pickup point. Suppose further that when the ballast conductance is at its highest

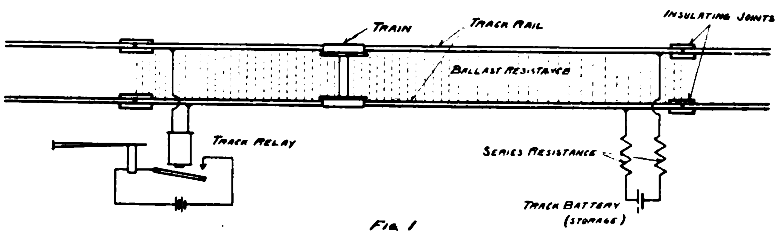

Fig. 1

value, as during wet weather, the track circuit is so adjusted that the relay just picks up. It is evident that when the ballast conductance has diminished, because of the moisture drying out or freezing, a conductance equal to the change in the value of the ballast conductance must be added between the rails in order to cause the relay to shunt.

If the contacts of the relay must be open when a single car is in the track section, the reciprocal of this change of conductance determines the resistance from rail to rail allowable in the wheels and axles of the single car. This, in turn, determines the length of section which can be operated, as the change in ballast conductance due to weather conditions varies directly with the length of section. In practice the limit of power available for supplying the track circuit is usually reached before the shunting limit, as the length of the section increases.

In considering the source of electrical supply for the track circuit, and its series resistance or equivalent, it should be noted

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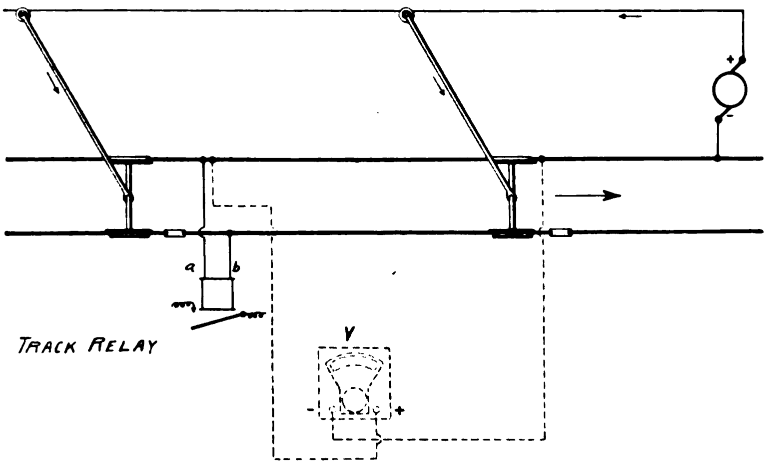
that the higher the voltage of the source, the higher the value of the series resistance necessary, and consequently the greater percentage variation in voltage across the relay with a given change of conductance between rails. The higher voltage means, then, a greater factor of safety as regards any variations in the shunting point of the relay, but also subjects the relay to wider variations of voltage.*

About eight years ago the Boston Elevated Railway Company had its new elevated lines nearly ready for operation and wanted them protected by a track-circuit automatic block signal system. The motive power was to be direct current at 550 volts and with



POTENTIAL ACROSS RELAY DUE TO RETURN POWER CURRENT

FIG 2.

ground return. One rail at least was to be continuous; that is, not divided into sections by insulated joints. Here, then, was a new condition of affairs with one of the rails of the signal circuit traversed by a foreign current of comparatively enormous volume.

Fig. 2 shows at once the difficulty which the signal engineer encountered. The power generator is represented by the conventional symbol. V represents a voltmeter which as connected

*This subject of track circuits was taken up by Mr. H. G. Brown in a paper read before the Institution of Electrical Engineers, last December.

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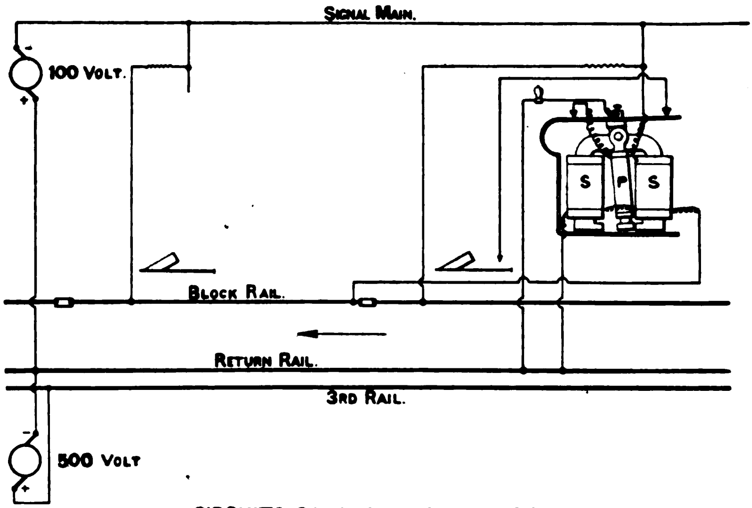
will measure the drop of potential due to the flow of return propulsion current over the continuous rail. Now with a train at the far end of the block from the relay, the latter has the same potential across its terminals as that measured by the voltmeter, for lead *a* connects one side at the same point as the positive lead of the meter, and lead *b*, the insulated rail, the wheels and axles connect the other side to the same point as the negative lead of the meter. Whether or not an ordinary electromagnet type of relay will close its contacts under these conditions depends on whether or not the voltage at which it is adjusted to operate is greater than the drop of potential caused by the return of power current over the length of rail measured by the length of block. In the case of the Boston Elevated the maximum drop which could occur over the return rail was limited, owing to the facts that the blocks were short and the return rail was bonded at close intervals to a structure having a copper equivalent of 14,000,000 cir. mils, from which the return current was taken to three power stations suitably spaced. These conditions made it permissible to use a relay whose voltage adjustment took care of any return drop which might occur, no alternating-current signal apparatus having been developed at that time.

In addition to the armature which distinguishes the steam-road direct-current relay, the one designed to meet the conditions on the Boston Elevated had a polarized feature, which would prevent the relay from closing its contacts in case a car failed to obtain a good ground on the return rail and grounded through the relay. On account of this feature the relay had two separate and distinct sets of magnets as shown in Fig. 3. The stationary set, *SS*, is connected across the rails; the swinging set, *P*, is connected to the main leading to the negative pole of the signal generator, the positive pole of which is grounded. This generator replaced the batteries used on the steam road.

Supposing the relay to have de-energized, the sequence of operations in closing the relay contacts is as follows: the signal current coming from the positive pole of the generator, via the return rail, passes through the stationary coils to the block rail; thence through the latter via the resistance to the negative signal main. This picks up the armature which closes the left-hand contact and completes the circuit through the swinging coils. The polarity of the latter being fixed, they will swing to

the right, if conditions are normal, bending the phosphor-bronze strip to which they are rigidly attached. This closes the circuit to the local control mechanism through the upper right-hand contact.

If the propulsion current from the car motors fails to obtain a ground on the return rail but flows through the stationary coils of the relay, their polarity will be reversed on account of the propulsion current flowing in the opposite direction to the signal current. This will cause the swinging coils, whose polarity remains fixed, to move to the left and open the right-hand control contact.



CIRCUITS CONTROLLING A BLOCK.
BOSTON ELEVATED RY.

FIG. 3

This Boston Elevated signal system comprises some 90 odd track circuits and 170 blades, including interlocked signals, and about 60 switches, the latter being distributed among five electropneumatic towers and two mechanical towers.

The next electric road to be equipped with signals was the North Shore Railroad near San Francisco. On this road several of the blocks were to be over 4000 ft. long, and there was to be a maximum of 8 trains of 4 motor cars each, taking about 1600 amperes per train at starting. The power station was to be in the middle. In this case there was no elevated structure of 14,000,000 cir. mils capacity to take care of the return drop of the power current, so the first alternating-current track circuit was installed.

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The system used was what is termed the alternating-current single-rail return, and is shown in Fig. 4. The direct-current generator of the Boston Elevated is replaced by an alternating-current generator or transformer, stepping down from propulsion power mains to a suitable voltage for transmission of current over the two signal mains. Instead of supplying the track circuits directly from the signal mains through a resistance, a step-down transformer is used with a resistance in its secondary.

At the other end of the track section is an alternating-current relay, of the type shown in Fig. 5. It consists of a *C*-shaped

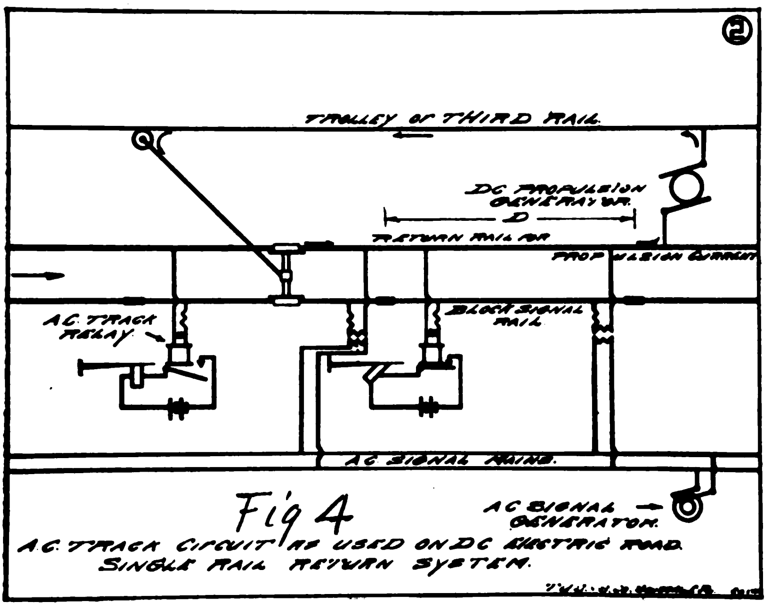

Fig 4
A.C. TRACK CIRCUIT AS USED ON DC ELECTRIC ROAD
SINGLE RAIL RETURN SYSTEM.

laminated core carrying a winding connected across the rails. One half of each pole-piece of the core is enclosed by a copper ferule. Between the faces of the poles is a sector of aluminum rotating on a shaft at right angles to its own plane. The shifting magnetic fluxes in the pole-pieces cause the rotation of the vane according to the well-known Ferraris principle, when sufficient alternating current passes through the winding to overcome the counterweight on the aluminum sector. The shaft carries the contacts. This relay, of course, is immune to direct current so far as the operation of its contacts goes. To limit the direct current passing through it to an amount below that

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which would dangerously heat it, or saturate the iron, the relay is shunted by an impedance coil, and a resistance is also inserted in one end of the leads. Going back to the other end of the track section, it is seen that the resistance in the secondary leads of the transformer is assisting to prevent the flow of direct current through the secondary winding of the transformer, in addition to its other functions in connection with the adjustment of the track circuit.

The track transformer and the impedance coil across the relay terminals are furthermore made with open magnetic circuits to keep down the density of magnetization caused by the flow of

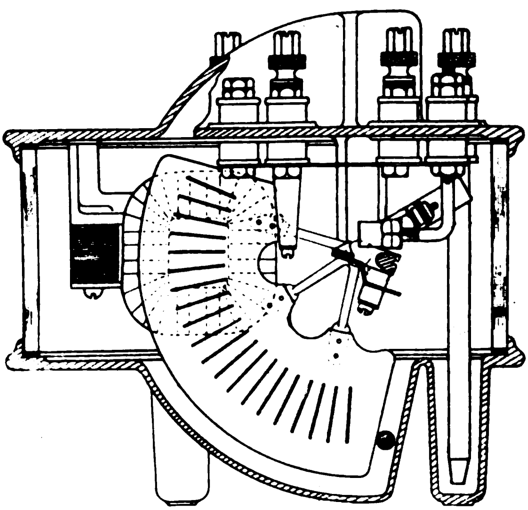

FIG. 5

direct current, due to drop of potential over the continuous rail spoken of in connection with Fig. 2.

On this particular installation about 10 miles of double track, and two-thirds of a mile of single track through a tunnel, were equipped with signals. The signal mains extend the length of the road and carry 60-cycle current at 2300 volts. They are supplied from the step-down transformers at the power house. One of the track sections is over a mile long.

The description of the foregoing system applies equally well to the system installed in the New York Subway, so far as the alternating-current track circuit is concerned.

The greater volume of direct current to be taken care of in the

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latter system was offset by the number of tracks, the steel framework of walls and roof, the close spacing of the sub-stations, and the shorter blocks. The signal mains are supplied with 60-cycle, 500-volt current by transformers located in the sub-stations, and stepping down from the high-voltage lighting mains. In emergency, 25 cycles stepped down from the propulsion circuits is used.

The New York Subway system comprises some 500 track circuits, 700 signals, and 230 switches, and has a record of one failure of apparatus to 3,359,167 movements, with no false safety indications in more than two years. The installation of a system using practically the same kind of apparatus has recently been completed on the Philadelphia Rapid Transit Company's new subway and elevated lines.

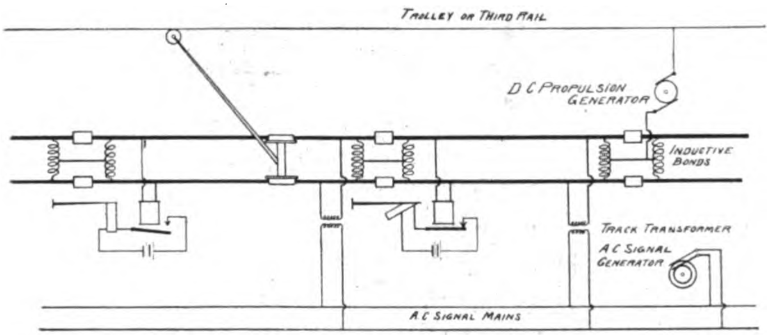

FIG 6

All the foregoing systems necessitated installing additional return conductors for the power current to compensate for the rail given up to the signal system, except where an elevated structure was available. The possibility of the use of a track circuit in which both rails should be used in common for signal and propulsion currents had been contemplated before this time. Local conditions on the Boston Elevated, the North Shore, and the New York Subway had made the single-rail system acceptable, however, and this led to deferring the development of the two-rail system shown in Fig. 6.

A path for the propulsion current around the insulating joints is provided for in the two-rail system in the form of the impedance bonds indicated in the figure. It is apparent that as the propulsion current divides so that each part passes

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around the iron core of the bond in opposite directions, its magnetizing effect on the core is zero, so long as the current divides evenly. On the other hand, the full impedance of the bond is offered to the signal current in preventing its passage from rail to rail.

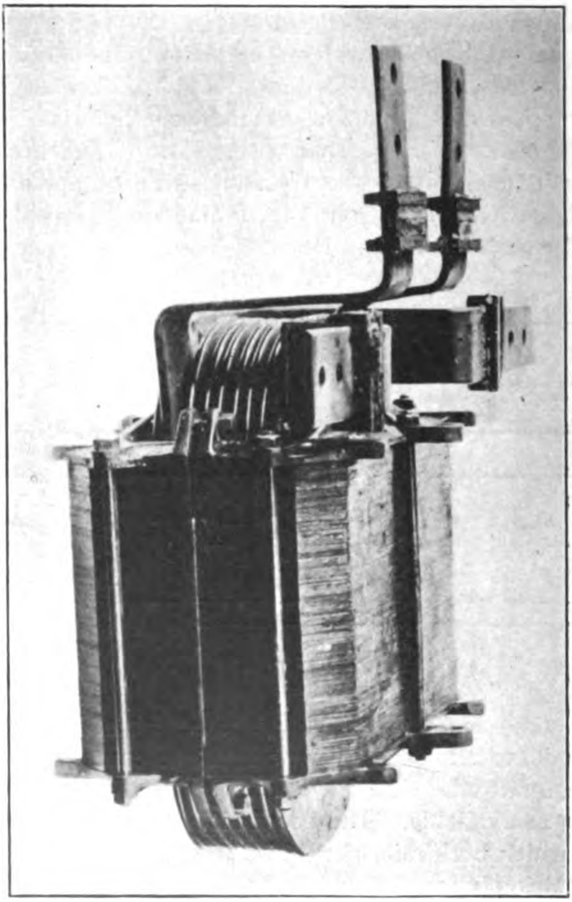

FIG. 7

Fig. 7 is a view of the bond out of its case. It consists of a shell-type core and heavy strap copper winding. The effect of unbalanced direct current is provided for, up to limits well beyond those met on properly bonded tracks, by using an open magnetic circuit and working the iron so far down on the saturation curve that the impedance of the bond actually rises with a

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small amount of unbalancing. These bonds may be installed between the rails of a track, as shown in Fig. 8, or just to one side.

The track transformers for this system are designed to have excessive magnetic leakage, and consequently a rapidly falling secondary characteristic, thus dispensing with the series resistance used with the battery or generator of the direct-current track circuit, or transformer of the single-rail, alternating-current track circuit.

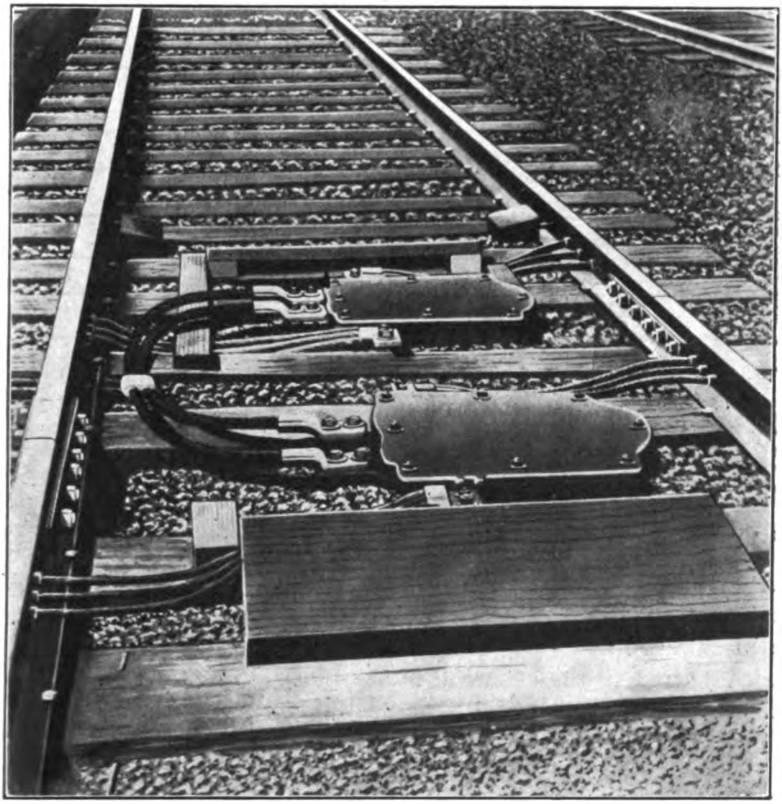

Fig. 8

Again the Boston Elevated was the scene of the installation of a new system, about 14 blocks of this type being installed during the winter of 1904–5, in the tunnel under the harbor, between Boston and East Boston.

The next installation of the double-rail return was on the electrified lines of the Long Island Railroad. The requirements here were 1100 amperes of return propulsion current per rail, and 800 amperes unbalancing. The track transformers and

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relays were grouped as shown in Fig. 9, instead of being placed at opposite ends of the blocks. 2200-volt mains carrying 25-cycle current supply a commercial 2200 to 55-volt transformer at each group of track transformers.

About 140 track circuits were installed and 19 miles of double-track road and 4.5 miles of four-track road were equipped with signals.

Last fall a third installation of the double-rail system was completed; namely, that on the West Jersey and Seashore Railroad. The sub-stations were to have a maximum ultimate capacity of 7000 amperes each, which, if distributed equally over the four rails, would mean 1750 amperes per rail.

The blocks were about 4000 ft. long and the innovation was introduced of placing the track transformer at the middle of the

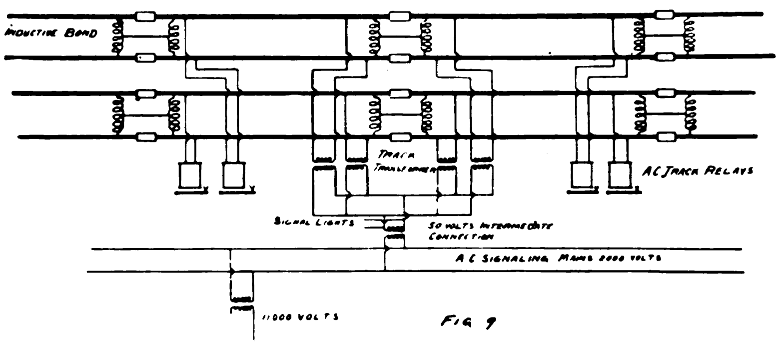

FIG 9

block (Fig. 10) with the relay at one end and a small step-up transformer at the other. The relay is really a motor with the armature rotating through about 45 degrees. The field winding is connected to the near end of the block, and the armature to the secondary of the small step-up transformer at the far end.

At each sub-station on the section equipped, a transformer between one leg of the power mains and the ground steps down to 1100 volts for the signal mains, which are carried on the poles below the power mains.

The signal system being installed in the electrified zone of the New York Central and Hudson River Railroad is also a two-rail system, using inductive bonds connected as in the systems described, but the relay is a two-phase induction motor with one phase fed from the track circuit, and the other from the signal mains, the difference in phase being obtained by the proper combination of the elements of the two circuits.

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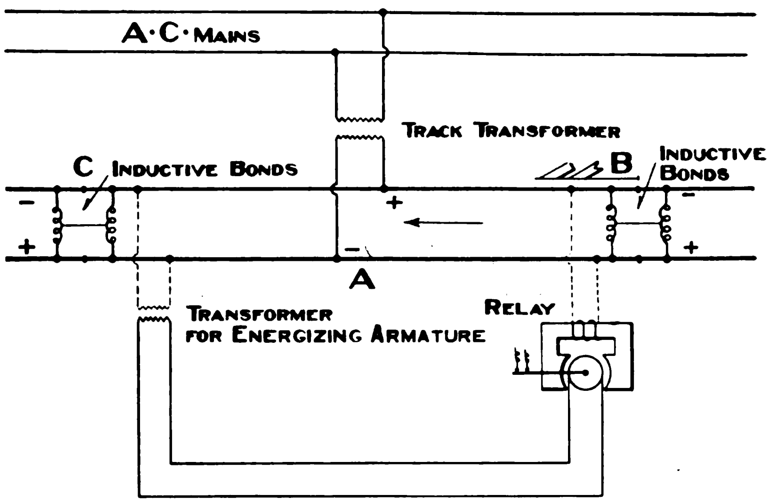
Having thus briefly described the different track circuit systems in operation on electrified roads, it is of interest to recall the discussion given in the earlier part of the paper of the simpler form in use on the steam roads, and then consider the changes made in some of the elements of the track circuit by the use of the double-rail return system. The latter system is chosen for discussion, as it constitutes the latest and most radical departure from the simpler form.

By the use of an alternating signaling current, we have an increase in the apparent resistance of the rails, due partly to skin effect and partly to magnetic induction. This increase is of course a function of the frequency.



Double Rail Return, Transformer In Middle Of Block
FIG. 10

We have also introduced an artificial apparent conductance between the rails in the inductive bonds, and they, together with the relays, introduce another inductive component.

The increase in the apparent resistance of the rails means, of course, higher voltage at the source of supply for the track circuit, and consequently more power. On account of the higher impedance of the rails and the consequently higher voltage required at the source of the supply of the track circuit, other things being equal, a given shunt applied to the rails at the relay will produce a larger percentage change of voltage across the terminals of the relay.

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On the other hand, where relays with a single winding are used, and there is leakage around an insulation joint from an adjacent block, a train at a given distance beyond the relay has less shunting effect on the relay, and there is greater danger of getting a clear signal with a train in the block, than with the direct-current track circuit.

This may be seen more clearly by an inspection of Fig. 11. The insulating joint, *A*, is defective, and current from the section on the right, flowing as indicated by the arrows, will tend to make relay *R* close its contacts. The resistance of the rails between the shunt, *S*, and relay, *R*, diminishes the effectiveness of the shunt as the effective resistance of the rails increases.

This danger may be diminished in various ways, among which are adjustment of the voltage of the source of current supply to the track circuit, so that to the relay is given just enough energy to operate satisfactorily under the worst weather conditions;

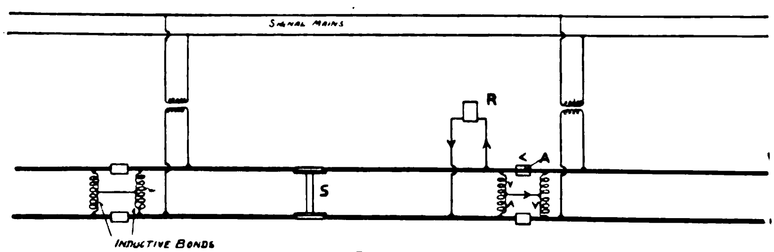

FIG 11

by arrangement of the track circuit apparatus, Fig. 9; and by the use of two element relays, Fig. 10, with the rails of adjacent blocks of opposite polarity.

When two-element relays are used, they should be as free as possible from any tendency to close the contacts because of repulsion or induction motor effects, caused by normal or accidental short-circuiting. In some forms of frequency relays the effects of open circuits must also be guarded against.

The introduction of artificial apparent conductance between the rails by the use of inductive bonds also has its advantages and disadvantages. Principal among the advantages is the smaller percentage change in voltage across the relay due to changes in ballast conductance with varying weather conditions. For the same reasons the shunt produced by the train causes less percentage change in voltage across the relay.

These two effects may be taken advantage of in the design of

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the transformer supplying the track, by making its secondary characteristic with a steeper gradient than where the bonds are not used. The greater the apparent conductance of the bond, the steeper should be the gradient.

The principal disadvantage arising from the introduction of the apparent conductance of the bonds between rails is the extra amount of current taken and the consequent drop in voltage between the track transformer and the relay, with the resultant increase in leakage through the ballast.

It is at this point that the electrical engineer laying out the power system for a road which is to use direct-current propulsion should realize that the higher the efficiency of his return system the cheaper will be the signal system, both in first cost and operation; and when the signal engineer of the road who is making up specifications for the signal manufacturers to bid on comes to the electrical engineer for information as to how much current per rail the bonds must carry continuously, and how much unbalancing they must withstand without causing the signal to go to danger, the electrical engineer must not state an amount which would give 40% loss in the rails, and in addition state that the inductive bonds must withstand 50% unbalancing. The larger the current to be carried by the bond, the greater the first cost of the copper.

The larger the amount of unbalancing the bond must withstand, the larger must be the capacity of the track transformers, the signal mains, and the generating apparatus, and the larger the amount of power to be supplied for the track circuits.

The greater amount of signal current to be supplied to the track circuit because of greater unbalancing capacity in the bonds is due to the fact that this unbalancing capacity is obtained by widening the air-gap in the magnetic circuit of the bond. This of course increases its apparent conductance and the current demands on the track transformers.

With roads using alternating-current propulsion, this unbalancing becomes of minor importance; first, because the return propulsion current is so much smaller; secondly, because the propulsion current being alternating, the actual resistance of the rail has a small ratio to the apparent resistance, and a comparatively large difference in the actual ohmic resistance of the two rails of a track may exist without making any great change in the propulsion current values in the two rails.

The inductive bonds for roads using alternating current for

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propulsion can therefore be made without an air-gap, and the only effect of unbalancing is to produce a voltage across the terminals of the relay of the same frequency as the propulsion current. This voltage being small with any reasonable amount of unbalancing, it may be taken care of in the frequency relay.

This frequency relay is so constructed that the presence of a voltage across its terminals of the same frequency as that of the propulsion current will not close the relay contacts, the presence of a higher frequency signaling current being necessary to accomplish this result.

The difference in unbalancing effect on roads using direct-current propulsion from that on roads using alternating-current propulsion, together with the higher frequency signaling current, made necessary when alternating-current propulsion current is used in order to operate the frequency relay, constitutes the principal differences in the relations between the elements of the track circuit as used on the two systems; so that what has been written of the double-rail track circuit on the direct-current road applies equally well, with the exceptions noted, to the same system on the alternating-current road.

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Discussion on "Some Facts and Problems Bearing on Electric Trunk-Line Operation," at New York, May 21, 1907.

W. J. Wilgus: There are so many points on which I fully agree with Mr. Sprague that it is perhaps well at the outset to dwell on one matter where we appear to disagree, and that is the relation of those engaged in the conducting of trunk-line railroad operation to the electrical engineering profession which is now gazing with hungry eyes on that enticing field of new endeavor—the electrification of trunk-line railroads. Without intending to indulge in the sarcasm and pessimism ascribed to our friend, the editor of the *Railroad Gazette*, I do believe with him that the cause of electrical engineering would be much more rapidly advanced if an effort could be made to bring the steam railroad official more closely in touch with the practical side of the application of electricity to the art of transportation. It is true that in the past the majority of steam railroad men have rather looked upon electric railroads as beneath their notice, but recent important developments in the change of motive power on some of the more prominent railroads of the country have dispelled this idea; and I feel certain that all steam railroad officials are now looking upon the future possibilities of the electrification of steam railroad traffic with keen interest and with a full appreciation of the magnitude and dignity of the problem.

Unfortunately they have so far felt barred from an intimate study of the subject because of the befogging of their minds by heated claims and counterclaims of the merits and demerits of various electric systems, coupled with the use of technical phrases with which they are entirely unacquainted. After all, the main features of the electrification of steam railroads are understandable to steam railroad men if technicalities can be avoided and the essentials described in ordinary homely language that can be grasped by the men not versed in the technique of electrical engineering. I therefore venture the suggestion that in general discussions intended for the enlightenment of the non-technical steam railroad men, the subject be treated as broadly as possible, with an absence of partizanship and with the use of plain non-technical terms. Furthermore, I believe that it would be conducive to the best interests of the electrical engineering profession to attract practical steam railroad men to a discussion of papers bearing on the electrification of trunk-line railroads so as to secure an interchange of views.

With respect to the conditions that will justify the use of electricity as a motive power in trunk-line operation, I believe that *evolution* will govern rather than *revolution*. In other words, there will be no sudden general substitution of electricity for steam as a motive power, any more than there was as a sudden jump from the small locomotive of the DeWitt Clinton

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type to the Mallet compound of to-day. Railroads, like all other human achievements, cannot stand still; they must either move forward or backward. It is generally recognized that their ability to move forward is now limited with steam locomotive practice, and that the overcoming of the defects inherent to the steam locomotive can only be accomplished by the use of electricity. It now looks as if the first movement in this process of evolution is the substitution of electricity for steam in congested passenger terminals at large centers of population where the public demands a cessation of nuisances incident to steam locomotives, and where the increasing volume of traffic requires increased capacity that cannot be obtained with the present motive power. The success of the New York Central installation in both of these particulars is an illustration of what can be accomplished, and imitation will surely ensue at other places where like conditions exist. Coincident with the change of motive power in crowded passenger terminals, is coming the use of electrically propelled trains on existing steam-railroad tracks between large centers of population where frequent units are necessary to accommodate the public. We already have an instance of this in the electrification of the West Shore passenger traffic between Utica and Syracuse, a distance of about 50 miles. In addition to these instances, where at this time the wisdom of the adoption of electricity as a substitute for steam is self-evident, there are a number of places in the West where the capacity of steam locomotives of the highest type is entirely inadequate to handle freight traffic on the pusher grades, and the only manner in which the increased capacity can be obtained is by means of electricity. With a start in the substitution of electricity for steam in the operation of congested terminals, connecting lines between large centers of population, and long pusher grades with heavy freight traffic, we may look with confidence to a gradual expansion of the use of the new motive power in other directions. For example, in the case of the New York Central the primary object of the use of electricity was to abate the smoke nuisance in the Park Avenue tunnel and to increase the capacity of the Grand Central terminal. When this decision was reached, it became self-evident that the use of the motive power should extend to the end of the suburban territory at Croton on the Hudson Division, a distance of about 35 miles. While the northerly terminus of the main line is thus planned for the present at Croton, it is probable that just as soon as the developments in the electrical field will warrant such action, the electric zone will be extended as far as Albany, a total distance of 142 miles.

This brings up the question of the respective merits of the three electrical systems now warmly advocated by their respective friends; videlicet, the direct current, single-phase alternating current, and three-phase alternating current. Looking at the matter from an electrical standpoint, it is very much to be

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deplored that the advocates of each of these systems have seen so much to condemn in the others, as this practice has frightened the steam railroad men from taking any decisive steps when there is such disagreement among those upon whom they must depend for guidance. If instead of blindly teaching the merits of one system to the exclusion of others, the electrical engineers could unite upon the axiom that each special condition should be carefully studied and the system adopted best suited to it, I feel certain that the cause will be further advanced. For instance, direct current was adopted for the New York Central installation at New York, among other reasons, because the clearances in the Park Avenue tunnel and the ordinances of the City of New York absolutely precluded the use of overhead construction; and yet we are told that a great mistake has been made and that no other system should have been used but single-phase alternating current with overhead construction. Entirely apart from any arguments, pro and con, of the relative merits of the two systems, it will be seen that physical and legal conditions prevented the adoption of any system other than the direct current. When there are no limiting conditions, and the steam railroad engineer is free to give full sway to the exercise of his judgment as to the selection among rival methods, he asks first, which is the most *reliable*? Accustomed to the use of long-tried steam locomotives, the breaking down of any one of which does not necessarily affect the movement of many others on the line at the same time, he naturally looks askance at the adoption of a new method of moving trains that carries with it the danger that in case of a disturbance at the power station or transmission lines, every train on the line will come to a standstill.

This question of *reliability* is much more important with a trunk-line steam railroad carrying passengers from remote points, and mail and express from over all the country, as well as suburbanites, than with local street-car systems. For this reason the conservative steam railroad man does not feel like making experiments with untried systems, no matter how alluring their advocates may make them, but prefers to select from systems which by long tried experience are proved to be thoroughly reliable. In fact on the more important trunk-line installations storage-batteries are now felt to be a necessity, not only to provide for violent fluctuations of load much greater in range than with ordinary street-railroad systems, but also to afford insurance against interruption of traffic due to minor breakdowns in power stations and transmission lines. The New York Central in its desire to secure reliability has provided not only storage-batteries, but also duplicate power stations with access for fuel by both rail and water, either of which can, in the event of the disablement of the other, run the entire system, by utilizing spare units and working overload. Duplicate transmission lines have been adopted for like reasons. Since the commencement of electrical service last December, events have already proved the wisdom of these precautions.

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The answer to this contention—that trunk-line railroads should use well-tried systems—is that no progress can be made unless something new is tried. In reply it may be stated that the trunk-line railroad is not the place to make experiments, but that inter-urban roads of minor consequence should be selected and the new system well proved before it is installed on a large scale in territory where its failure may have disastrous results.

Further commenting on the necessity for a study of local conditions, I have recently had in my charge the adoption of an electric system for operating combined freight and passenger service through a double-track tunnel now under construction. In view of the claims made by the advocates of different systems, it seemed wise to prepare the specifications so as not to cramp or restrict the judgment of the competitors, but leave the widest latitude for ingenuity and exercise of skill consistent with the accomplishing of the desired object. The invitation to domestic and foreign companies, in addition to asking for bids, also requested the filling in of blanks to show the annual costs, including interest charges, depreciation, taxes, and operation. The result showed conclusively that for that particular installation, the direct-current system was the cheapest in both first cost and annual cost, to the extent of from 20 to 25 per cent. less than its nearest competitor.

With your permission I would like also to give another illustration of the lack of wisdom in making broad generalizations from which to draw specific conclusions. We are often told that the overhead single-phase system should be used because of the advantage of requiring no sub-stations and sub-station attendance, but nothing at the same time is said about the higher cost of alternating-current locomotives for performing the same service, nor the higher cost of overhead construction as compared with the third-rail. About a year ago a pamphlet emanating from an eminent authority stated that on four-track trunk-line territory overhead construction would cost about $16,000 per mile, when as a matter of fact a recent actual installation has cost over $50,000 per mile! Also in a recent installation, while the first cost of the adopted system is somewhat less than one of the rival systems, still the increased consumption of current on one portion of the territory, capitalized, amounts to a very large sum. This amount added to the cost of installation, makes the equivalent cost considerably in excess of its rival. I am merely mentioning these instances as showing the necessity for fairly setting forth all sides of a problem before drawing a conclusion that may be entirely wrong; in fact I do not know of any important question of the day that so much requires absolute openness and frankness, with a careful examination of all sides of the case, as the adapting of electricity to trunk-line practice. Any concealment of the facts reacts sooner or later to the detriment of those responsible therefore and to the financial embarrassment of the suffering company.

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I cannot too strongly endorse Mr. Sprague's remarks bearing on the wisdom of adopting the multiple-unit system for handling suburban service. The New York Central has already reaped its reward in adopting this method, in the elimination of practically all of the delays of train service at the Grand Central Station, delays that heretofore largely resulted from the multiplicity of movements of steam locomotives in passing to and from the engine-house facilities and in switching from the head to the rear end of trains; in fact, apart from other improvements made at this terminal, the use of the multiple-unit system has at this time resulted in an increase in the capacity of the station of at least 33 per cent. Moreover, the rapid acceleration of this character of equipment as compared with locomotive practice has resulted in the ability of the operating department to maintain schedules with a reduced rate of speed between stations. While on this subject of acceleration it might be well to add that in making a selection between the rival electric systems, relative acceleration should be compared not only in connection with the movement of suburban trains but also through trains hauled by electric locomotives. Some recent observations have demonstrated to me the marked difference of acceleration between the two principal electric systems. In changing motive power from steam to electricity on trunk-line railroads, this question of acceleration is one of the greatest attractions; it should, therefore, not be lost sight of in deciding upon any electric system which may offer no greater advantages in that regard than the steam locomotive that it displaces.

Another point mentioned by Mr. Sprague that seems worthy of special notice, is bonding of track rails. The New York Central has realized the wisdom of its course in adopting bonds concealed beneath the fish-plates, as there has been no loss from their theft; whereas I believe that on other roads where this precaution has not been taken, electrical operation has been seriously interfered with by the theft of exposed bonds.

In thus venturing a word of advice for closer relations between the steam railroad engineer and the electrical engineer, and greater frankness and cool reason in the discussion of the relative merits of the various electric systems, I may be pardoned a word to the electrical manufacturers in doing their part to popularize with steam railroad men the use of electricity in solving trunk-line problems. Always having in mind the primal elements of safety and reliability, all inventive genius of the great manufacturing corporations in this country should be bent on devising means of accomplishing a desired result at less cost, as this will mean in the end such an increase in the use of electricity as a motive power as to more than compensate for the comparatively small loss in decreased unit prices of apparatus. One of the promising movements in this direction is the hints that have been given of the possibility of substituting for the expensive synchronous converters and sub-station attendance of the

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direct-current system, a very simple device which will cost very little and require no attendance. This one feature, if successful, will go far toward strengthening the hand of the steam railroad enthusiast in extending the use of electricity more generally than now seems possible. The signal field is also one in which there is room for improvement in reducing costs of installation so as to make the use of electricity feasible from a financial standpoint. The use of electricity at the present day requires the throwing away of old type signals and interlocking systems and the installation of an entirely new system at a vast cost, due to the necessity for the use of the track rails for return propulsion current. On one of the branch lines of the company with which I am connected the substitution of electricity for steam has been indefinitely postponed because of the attendant greater cost of making a change in the block signals and interlocking apparatus; but I am pleased to say that one of the electrical companies now gives ground for hopes that a new method has been devised which will do away with the necessity for the more expensive portions of the apparatus and so far reduce the cost of the change of signaling as to make feasible the electrification of the branch road. It has seemed wise to give these illustrations as having a bearing on the rapidity of the process of evolution of change of motive power on trunk-line railroads.

As to the relative merits of overhead and third-rail working conductors, steam-railroad men have been more or less alarmed at the freedom with which contending enthusiasts argue as to the danger attendant upon the selection of either. It must be conceded that in return for the many advantages that come with the use of electricity, there are certain disadvantages; among these is the added danger from the use of working conductors, whether third-rail or overhead. The question simply simmers down to the selection of the system which appears to offer the least danger. Mr. Sprague has exhaustively covered the merits and demerits of each, and it remains for the steam railroad man to make a selection, having in mind the desiderata of non-interference with the view of signals, elasticity in the adjustment of tracks to new grades and alinement and the laying of additional tracks, minimum danger from derailments, safety to employes, and economy of maintenance.

I realize that my remarks on Mr. Sprague's exhaustive paper are very general and throw very little specific light on the problems that he discusses, but I feel that I might be pardoned for dwelling on a few of the features that have seemed wise for all of us to bear in mind in attempting to work together in bringing about as rapidly as possible the substitution of electricity for steam in places where progress demands increased capacity and the abolition of many drawbacks that necessarily accompany the use of the steam locomotive.

Lewis B. Stillwell: The Institute is to be felicitated upon the presentation of a long and interesting paper by a member who

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in the past has contributed largely, perhaps more largely than any other living man, to the utilization of electricity for traction purposes. With much, perhaps all, that this paper states in its first dozen or fifteen pages I am sure that we will find our opinions in agreement. We have noted a tendency of some electrical engineers to indulge in prophecy; the fact that some of us have difficulty in discussing railroad finance and operation unless we confine ourselves to glittering generalities has been frequently observed; that the hope of financial profit is the underlying motive which induces the capitalist to undertake electrical enterprises is a part of our engineering creed.

It is sometimes asserted also that an unfortunate tendency and limitation of engineers, as a class, is to concentrate their attention too closely upon certain features of a general problem and to lose sight of other features essential to a comprehensive and accurate mental prospective. Realizing this, it is satisfactory to note that the preliminary pages of the paper this evening aim to assist members of the Institute by suggesting a broad view of the general problem of electric trunk-line operation. It is distinctly disappointing, however, that, after casting his eye over the broad prospect which now appears to offer so inviting a field for the realization of increased earnings and decreased operating expenses by gradual, well-considered, and systematic extensions of electrification, the author should spend so much time and effort examining details of construction of assumed alternating-current and direct-current car equipments that he is able to bestow but a passing glance upon the sub-stations required for direct-current operation, and but hastily to examine the contrasted systems of transmitting power from coal pile to moving train. Herein the paper entirely fails to convey an accurate idea of their relative advantages and limitations.

In the paper of the evening, as also in his interesting contribution to the discussion of the paper which Mr. Henry St. Clair Putnam and I had the honor to present at the meeting of January 25, the author takes issue with certain opinions which I have expressed relatively to the question of standardization of electric railway equipment and the relative merits of direct-current and alternating-current motors for trunk-line operation. In the paper before us he says.

> But above the discordant notes, and in the turmoil of varied developments there rises now and then the cry of standardization, not only such as is natural and not prohibitive of new advances in the art, but wholesale, explicit, and exclusive. For example, in a recent paper before this Institute, the view was expressed that but a single plan—the high-tension overhead trolley, with 15 cycle, single-phase alternating-current motors—was possible of serious consideration on trunk-line service, and that this system should now be adopted and standardized, despite the fact that there was not in existence a single equipment of this character in practical railway operation!

It is obvious that Mr. Putnam and myself failed to convey to the author of this evening's paper an accurate understanding

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of our position, and lest others also may have misunderstood our meaning I may be permitted to quote from the paper and its discussion the following paragraphs relative to "Standardization":

Engineers constituting the membership of this Institute owe it to themselves, as well as to their clients, to use every effort, without prejudice and without fad, to prevent waste by opposing the introduction of apparatus which from its limitations cannot solve the general problem of railway electrification; and it is to be hoped that they will use their united influence to fix proper standards as rapidly as this establishment may be consistent with progress. * * *

The necessity of proper standardization is obvious. Specifically it would seem feasible and eminently wise to agree upon standards of practice in respect to the following:

(a) Location of third-rail.

(b) Location of overhead conductor used with single-phase alternating-current system.

(c) Frequency of alternating-current traction systems.

It is equally desirable but probably less easy to agree upon a standard system of multiple-unit control for train operation. * * *

The position which we take in this matter may be stated as follows:

a A general view of the railway field, including freight as well as passenger traffic, obviously shows that for anything approximating a general solution the single-phase alternating-current system is decidedly superior to the 1200- or 1500-volt direct-current system. This conclusion is corroborated by calulations easily made and based only upon established facts.

b The admitted advantages of electricity in respect to increased earning power and decreased cost of operation are such as assure in the near future rapid increase in the use of electricity by railway systems now operated by steam.

c The necessity of standardizing frequency rests practically, although less directly, upon the same arguments as have induced railways to standardize track-gauge, train-line, and steam-line.

In other words, the significance of our estimates of comparative operating costs is that the results, viewed in connection with admitted facts in respect to increased earnings, indicate that a general electrification of important railway divisions, and even of trunk lines, is coming much more rapidly than has been generally realized, even by electrical engineers; and the lesson to be drawn from this conclusion is that we must standardize as promptly as possible everything essential to convenient interchange of rolling stock.

Mr. Putnam and I have said nothing which excludes from further consideration the three-phase alternating-current system or any other alternating-current system, neither have we opposed the use of direct-current motors at any voltage in any kind of service, except trunk-line service in which it is proposed to substitute the electric motor for the steam locomotive. The line which divides trunk-line service from interurban service, of the class to which hitherto electricity has been applied, is sufficiently distinct, in most cases, to be recognized without difficulty. For interurban service I have used, and may continue to use for some time to come, direct-current equipment. Every real improvement in electric equipment adapted to rolling stock, whether that equipment be of the direct-current type or the alternating-current type, has its value. Each specific case of proposed installation obviously calls for careful comparison

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of available and adequate systems. Such comparisons, however, if they are to lead to conclusions that shall stand the test of time, must take into account not only existing and available equipment, but must recognize also tendencies in the development of the art, and consider probabilities of future extensions and possible connections of the specific line under consideration.

For trunk-line operation I have held and still hold the opinion that the 15-cycle, alternating-current, single-phase system possesses inherent characteristics which, in this class of work, constitute controlling advantages as compared with any direct-current system that has been suggested, or is liable to be developed into an operative system. With this opinion the paper of this evening joins issue. In the oral discussion of the paper of January 25 the author of this evening's paper stated his position with emphasis by saying:

> I am going to make a prophecy, that on a large number of lines which can by any stretch of imagination be considered as subject to a reasonable prospect of electrification, 1200 or 1500 volts will on any present development known, give better results in every way than the alternating-current, 15- or 25-cycle overhead system.

The paper before us while presenting certain data and opinions purporting to sustain the contention that the 1200-volt direct-current system is superior to the 15-cycle alternating-current system, presents no sufficient and fairly comparable data upon which any such conclusions can be based. The only data which it presents in the way of a comparison of the relative outputs, speeds, and weights of the contrasted types of motor are those in which a direct-current motor rated at 240 h.p. and an alternating-current, 25-cycle motor rated at 125 h.p. are compared. A pyramid cannot be made to stand long upon its apex unless propped up, and no conclusions as broad and far-reaching as that which this paper apparently endeavors to establish can be based upon a single comparison of this kind. Even this single exhibit obviously requires material correction before it can be used properly as a premise for the conclusions which the author seeks to draw. It is defective for the following reasons:

1. It compares two motors of equal weight. This comparison used as a basis for a general conclusion is, obviously, unfair to the alternating-current motor, as it takes advantage of the fact that increase in the size of motors of any type, alternating current or direct current, implies reduction in weight per horse power. Had the comparison brought together two motors of equal output, the ratio of weights would have been far less than is the ratio of output when equal weights are considered. The particular case of a motor-car equipment in which it appears that four 25-cycle alternating-current motors would be required to do the work of two 550-volt direct-current motors is one which has come up in my own experience, but, obviously, it is no proof that similar relations would hold, for example, in equipping a locomotive with a given aggregate horse power.

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2. The comparison is made with a 550-volt, direct-current motor weighing without gear, gear-case, and pinion, only 23 lb. per h.p. (one-hour rating). This is extraordinary light and indicates that the motor is, in respect to the relation of weight to output, superior to anything in general use. The latest 200-h.p. motors offered within the last 60 days to the Interborough Company by our leading manufacturers weigh, respectively, 28 and 30 lb. per h.p. (one-hour rating). The alternating-current motor in Mr. Sprague's comparison, on the other hand, is characterized by a higher relation of weight to output than other single-phase motors of comparable output in the market.

3. The comparison is between a direct-current and an alternating-current motor operating at 25-cycles, not 15-cycles, which is the frequency suggested by Mr. Putnam and myself. The 25-cycle single-phase motor has a far higher ratio of weight to output than the 15-cycle motor of the same output.

The paper emphasizes the statement that "Capacity is the keynote of equipment." With this conclusion few will differ. In our consideration of capacity of equipment, however, we should not limit our attention to the motor but should take into consideration, also, the comparative methods of transmitting power to the moving trains. In general, the choice of a system will depend upon the ratio of capacity as measured in tractive effort to aggregate cost of equipment.

I have read the paper of the evening somewhat hastily and possibly may have overlooked an adequate statement of the advantages of the alternating-current systems which result from the elimination of the converter substations. These, as is well recognized, are a very expensive element of the direct-current system as it would be applied to anything resembling a trunk line—expensive not only in first cost but relatively still more so in annual cost and in complication of the distributing system. There are to-day in operation in this city somewhat over eighty 1500-kw. converter units for the purchase and installation of which I have accepted responsibility. While this machinery is doing excellent service, I know enough of its cost and limitations to realize that for trunk-line railroad operation in the broad sense a system which employs the converter as an essential link between the coal pile and the train must give way to a system which eliminates this link, provided the single-phase, alternating-current motor is designed and manufactured with anything approximating the care which to-day is bestowed upon the direct-current motor.

As I have said, a pyramid should not rest upon its apex; general conclusions, too, in respect to the very important question under consideration, should not be based upon comparison of a single representative motor of each size. Such comparison should rest upon comparative data prepared by competent designing engineers, working without prejudice in favor of one system or the other, and should comprise essential facts covering a

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considerable number of motors of various output, designed for the same service. It is to be hoped that some of the designing engineers of our manufacturing companies will prepare and present such data in connection with the discussion of this paper.

Meantime, however, I may say that only last week with reference to a specific installation which I am studying, I obtained from the engineers of one of our large manufacturing companies comparative figures relating to 15-cycle, single-phase, alternating-current motors of 200 h.p. at one-hour rating, and 600-volt, direct-current motors of the same output. These motors are practically identical in speed when delivering 200 h.p. The data in which I was particularly interested are the maximum vertical dimensions and the weights of these motors. The maximum vertical dimension of the alternating-current motor is 36.5 in.; that of the direct-current motor is 1.625 in. less. The weight of the alternating-current motor is 6280 lb.; that of the direct-current motor is 6000 lb.: both of these weights are exclusive of gear-case and pinion. The alternating-current motor requires a wheel-base one foot longer than is necessary with the direct-current motor. The ratings in the case of both motors are based upon the same rise of temperature without forced ventilation.

I am not sure that I understand the author's reference to the implied necessity of increasing the current-carrying capacity of steel conductors. He quotes from the report of the commission of the recent International Electrical Congress to show that on 80-lb. rails the ratio of impedance to resistance at 25-cycles is about 9 to 1. This difference is, of course, well known; but in transmitting a given amount of power by single-phase alternating current through overhead trolley and track return at 11000 volts, even when a frequency as high as 25 cycles is employed, the reduction in current implied by the increased voltage makes the total drop in the circuit, as measured in percentage of applied potential, less than $\frac{1}{40}$ the drop of a direct-current system operating through the same circuit at 1200 volts.

It should be noted carefully that while the only comparative data given with respect to motor performance relate to the 550-volt, direct-current motor, the paper implies that in competition with the alternating-current system a direct-current potential of 1200 volts will be used. It is for our designing engineers to supply adequate data, but I venture to express the opinion that comparing the 15-cycle, single-phase, alternating-current motor with the 1200-volt, direct-current motor, the latter will, in general, have very little, if any, advantage in respect to dimensions or weight. Moreover, it is not to be lightly assumed that synchronous converters delivering 1200 volts would be found as cheap and as reliable as the 600-volt machines now in use.

When we come to consider the auxiliary car equipment and wiring there is a very radical difference in favor of the alternating-current system. In this field as in the lighting field the transformer is the key to the solution of the general problem of

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transmitting energy at reasonable cost and utilizing it at safe and easily controlled potentials.

W. B. Potter: Using the word system in the sense of meaning the different modifications of direct and alternating current, I think all will agree that the state of the art is not such as to warrant the recommendation of any particular system as the standard and the only standard for future consideration. With reference to existing installations, the 600-volt, direct-current system and apparatus is certainly a recognized standard, which is more than can be said of the apparatus on any of the other installations, at least in this country. In nearly every case where a choice between systems is considered, there are controlling conditions with respect to financial advantages or local requirements which are of sufficient prominence to determine the particular system most suitable for the case under consideration. The proper attitude of the engineer toward commercial undertakings, with which most of us have to deal, should be that of an investor, his reputation being his capital and his dividends being in direct proportion to the economic success of the work for which he is responsible. I feel that Mr. Wilgus has well expressed this sentiment in saying that an important trunk-line railroad is not the place for experimental development, but that such work should be done on branch lines where failure or partial success would inconvenience a smaller number of persons. To a large degree new types of apparatus can be perfected by manufacturing companies, by experimental operation on suitable tracks; but in the actual operation of apparatus conditions invariably arise that do not develop under the control of the designers and which can only be eliminated by such advisable modifications in design as become apparent from a careful study of the apparatus in service.

For a number of years the improvement in direct-current apparatus has been principally with respect to its mechanical features. Within the last few years, by the application of commutating poles, there has been a decided improvement in commutation, particularly with direct-current railway motors. These motors, by reason of physical limitations and the fixed position of brushes necessary for operation in both directions, are particularly difficult to design electrically. From present indications it would appear that for other than bi-polar motors the recognized standard direct-current railway motor will undoubtedly be provided with commutating poles. Granting a motor of suitable capacity, the character of the commutation is of the utmost importance to the operator, since defective commutation means decreased reliability, increased cost of maintenance, and a degree of supervision out of all proportion to the other parts of the motor.

This problem of commutation, which has been so effectively solved in the case of the direct-current motor, is one of the principal difficulties to be overcome in the single-phase, alter-

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nating-current motor. The commutation of this is inherently inferior. Another feature of the alternating-current motor incidentally affecting commutation is the number of armature revolutions relatively to the car-speed; the armature speed is somewhat higher than that of the direct-current motor. The higher speed of the armature is not necessarily a feature of single-phase motor design, but owing to the comparatively greater weight of this motor it is desirable to run the armature at as high a speed as is consistent with satisfactory operation of the bearings.

The single-phase motor is a comparatively recent development. We have good reason to expect substantial improvements in its design, particularly with respect to commutation; and I am pleased to say this evening that the prospects are particularly encouraging for a single-phase motor with commutation as good if not better than that of direct-current railway motors without commutating poles, and with an armature speed only slightly higher than that of the direct-current motor. As this improvement in commutation is got without the use of resistance leads, the internal losses incident to such leads, or the losses due to local current in the armature, are largely avoided and the efficiency of the motor is improved. The weight of such a motor will still be probably about 25% greater than that of a direct-current motor of the same rated capacity.

These improvements do not affect the application of the different systems, except that they may result in reducing the cost and maintenance of the single-phase apparatus. They do, however, raise the quality of the apparatus more nearly to that used in present direct-current practice.

The 1200-volt direct-current system, to which special reference has been made by Mr. Sprague, is substantially in line with present-day practice for 600-volt apparatus. The commutation gives every evidence of being as good as with 600-volt motors, the only provisions necessary being additional insulation both with respect to the coils and creepage distances on exposed surfaces. With respect to the higher voltage direct current, I would suggest that 1200 volts be accepted as the next higher standard above 600 volts. The use of a number of intermediate voltages would introduce a variety of apparatus not suitable for general use, and necessarily more expensive, as it would be manufactured in limited quantities only. On account of the practical relation of speeds easily obtained with the series-parallel combination of the motors, 1200 volts afford better opportunity for interchangeable operation with 600 volts than with any intermediate voltage.

As an illustration of the attitude of operating companies concerned in getting apparatus most suitable for their service, I would mention that at the present time there are being manufactured for use in this country, railway apparatus for 600- and 1200-volt, direct-current systems, a 6000-volt, three-phase system, and a number of 25-cycle, single-phase systems of different voltages.

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Charles F. Scott: The author makes comparisons between direct-current and single-phase, alternating-current apparatus. I have been particularly interested to detect his method in arriving at conclusions which are so largely at variance with those of some other engineers.

First of all he lays stress upon the relative capacity of the motors of the two types as being one of the important and controlling elements in reaching a decision. He takes certain data and a certain basis of comparison, and from these reaches apparently logical conclusions. The question then arises, are the data and the basis of comparison correct? If not, are there not other data and another basis of comparison from which conclusions may be drawn by the same method, but perhaps with different results?

It seems to me that a number of points which Mr. Sprague has taken up are comparisons on a particular basis, and that he has not considered fully the different methods or conditions under which the two motors may operate; for example, in comparing the curves of the two motors, he shows that the alternating-current motor has at light load a much higher speed than the direct-current motor under the conditions which he has taken. There is an apparent conclusion, therefore, that the alternating-current motor is lacking in the excellent characteristics possessed by the direct-current motor. He has failed, however, to call attention to another point; that is, the ready adjustability of voltage in the alternating-current system by means of voltage taps from the transformer. By this means the motor, instead of operating to its highest speed under a single applied voltage, which is the usual condition with the direct-current motor, may have a lower voltage applied. It may, therefore, develop different torques at different speeds, depending on the controller position. Under the control, therefore, of the motorman, the alternating-current motor is not limited to a single law of acceleration, but may have different rates of acceleration, adjustable as desired; it may, for example, have the same mean acceleration from start to maximum speed as that of a direct-current motor, but with a less maximum rate of acceleration.

Another point in which changed conditions were not taken into consideration is that of rail-loss. Although the loss per ampere may be greater, the loss per kilowatt may, as pointed out by Mr. Stillwell, be much less.

It appears that the author, in his treatment of the subject has, unconsciously perhaps, assumed the direct-current motor and its characteristics as the ideal of perfection, so that wherever the other motor has different characteristics, these characteristics were naturally and *per se* objectionable. At any rate, he has apparently not recognized or emphasized certain advantages on the side of the alternating-current motor, In certain cases the voltage control can give a higher speed than

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normal to a motor in service. The application of higher voltage gives not only higher speed, but greater output as well. Something of the same nature is attained by field-control in the direct-current motor, but the field-control is a method of adjusting speed without increasing the capacity of the motor. The same voltage is applied, and the permissible current through the motor remains the same, and hence its capacity is not increased. But with the alternating-current motor an increased voltage is applied to the motor which gives an increased output, with the same current going through its armature. The paper, furthermore, gives but little consideration to the advantages inherent in the alternating-current system between the power house and the train, through the elimination of synchronous converters and the reduced current to be carried. The rheostatic losses in direct-current equipments, a matter which in some kinds of service is of considerable importance, has not been touched upon.

The matter of electrical braking has been referred to. A paper on braking with single-phase motors is to be presented at the next Convention by Mr. William Cooper. The paper will deal with a method which has been worked out and fully tested, whereby it is found that the single-phase motor lends itself admirably to braking, covering, as I recall, all the desirable qualities in braking which have been called for by the author and doing far more than has been shown possible with the direct-current motor.

N. W. Storer: The question of third-rail versus overhead construction for electric railways is a matter concerning which it is unnecessary to theorize, because, with the large systems now in operation or about to be put in operation, it will very soon be settled by experience.

I desire to take issue with the author in regard to some statements concerning single-phase equipment, as information that I have is entirely at variance with what appears in the paper. In the first place, there are given fifteen so-called differences between direct-current motors and alternating-current, single-phase motors. These might have been called, "The advantages of direct-current motors as compared with single-phase motors," as this is what they are made to appear. Although many of these are of little consequence they will nevertheless be considered in order.

1. "The input of current in one is continuous; in the other, intermittent." Quite true, but the draw-bar pull is quite as effective in one case as in the other.

2. The direct-current motor has a solid frame like the single-phase motor. It has, further, two or more laminated poles bolted in, and if the interpole construction is used has as many more relatively small and delicate poles. The alternating-current motor as built by the company with which I am connected has, in all sizes up to a diameter of 38 in. field punchings made in a single piece and built up and keyed in the frame,

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making it as solid a construction as an armature on its spider. The claim for less rigidity in the single-phase motor is, therefore, not sustained.

3. "One has exposed and hence freely ventilated field-coils; the other has field-coils embedded in the field-magnets." It is known to most motor designers that coils in contact with iron will dissipate heat much faster than when in the open air. This is especially true of coils in an enclosed motor. I have repeatedly noticed that motor field-coils which have been removed on account of roasting, have shown the insulation in contact with the pole pieces to be in good condition, while other sides were badly roasted. I know, therefore, that in respect to ventilation of field-coils, the single-phase motor is superior to the direct-current motor. Smaller cross-section of coils also allows the heat to be radiated better in single-phase motors, and the fact that a large part of the loss in the motor is concentrated in the field iron will enable the motor to dissipate a much larger amount of heat for a given temperature-rise than will a direct-current motor.

4. Concerning "polar clearances." Many thousands of direct-current motors are to-day in operation with a clearance of $\frac{1}{8}$ in. to $\frac{3}{16}$ in. between poles and armatures, and in practically all cases where more than $\frac{3}{16}$ in. clearance is used it is for electrical reasons. Further, while the smaller air-gap used for single-phase motors was at first much feared, the fears have proved to be without foundation and the present clearances of from 0.1 in. to 0.15 in. have proved to be ample and fully as good as 0.15 in. to 0.25 in. in direct-current motors, because there is no unbalanced magnetic pull.

5. Concerning "torque." The torque of an armature is the pull it will exert at one-foot radius. Therefore it makes no difference in the result whether it is obtained with large flux and few armature conductors, or vice versa.

6. "A much larger diameter of armature and commutator, and runs at a much higher speed." This is a very general statement: what are the facts? The armature diameters ordinarily run from 5 to 15% larger than for direct-current motors of corresponding output. It is undoubtedly true that the armature speeds of the earlier single-phase motors were much higher than the speeds of corresponding direct-current motors; at the present time, however, the speed at the nominal rating of the motor is practically the same as that of direct-current motors, and the maximum operating armature speeds are within the safe limits set for direct-current motors.

7. Concerning "gear-reduction and gear-pitch." The gear-reduction depends, of course, upon the speed; and as far as gear-pitch is concerned, I wish to say that the same gear-pitch is used for single-phase motors as for direct-current motors of the same capacity.

8. "The windings of one are subject to electrical strains of

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one character; in those of the other the strains are of rapidly variable and alternating character." No conclusion is drawn from this. It may be of interest to know that there have been a number of instances where the single-phase motor has broken down in service on a direct-current section of the line, necessitating cutting it out of the circuit; but when the car reached the alternating-current section of the line it has been again connected in circuit and operated satisfactorily, thus indicating that the electrical strains with alternating current are less severe than with direct current.

9 and 10. Concerning the "variable torque of the single-phase motor." No comment is made as to the relative merits of uniform or pulsating torque. In a recent discussion before the Institute, Mr. Potter called attention to certain characteristics of the torque exerted by an alternating-current motor, especially when it reaches the slipping point of the wheels. It was stated that there is an apparent advantage in the pulsating torque, because, when the motor starts to slip it does not immediately decrease its mean torque, as is done in the case of the direct-current motor, but slips in a series of jerks apparently regaining the hold on the rail at every pulsation.

11. Concerning the "number of poles." The paper states that the direct-current motor has "two or four main poles only." No direct-current motors built in the last 15 years except those on the New York Central locomotives have less than four poles. The paper states that the alternating-current motor has "eight to fourteen poles." The single-phase motors built by the company with which I am connected have four poles for all sizes up to and including 125 h.p. The largest single-phase motor thus far built has a capacity of 500 h.p. It has but 12 poles.

12. Concerning "a high torque while standing still." As we understand the matter, railway motors are designed to move a train rather than to hold it at rest. At the same time we know that the single-phase motor is amply protected against mistakes of motormen in leaving the current on the motor for a half-minute or so with brakes set.

13. Concerning "resistance in commutator leads." It is well known that the resistance leads used in single-phase amatures are for the purpose of reducing to a minimum the loss due to the transformer action in the short-circuited coil. Their presence is fully justified and the efficiency is higher than it would be if they were not used.

14. This refers to relative weights concerning which I shall have something to say farther on.

15. On this point I agree absolutely with the author. There is one type of construction to which the single-phase motor is not adapted. This is so far employed in only a single case.

More or less is said in the paper concerning the lower efficiency of the single-phase motor, and inference might be drawn that

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it is about 10% lower than that of the corresponding direct-current motor. Just to show what modern motors are capable of doing, I give below in parallel columns the efficiencies of corresponding sizes of direct- and alternating-current motors at different percentages of their full-load torque.

Per cent. of full-load torque	Direct-current 90 h.p. motor	Alternating current 25-cycle, 100 h.p motor	Direct-current 200 h.p. motor	Alternating current 15-cycle, 200h.p motor
125	86.25	82.	88.8	87.3
100	86.8	85.	89.	88.
80	87.	86.	89.2	88.3
60	86.5	86.8	88.8	87.7
40	85.	86.	87.	85.
25	82.	82.5	84.	82.

From this it does not appear, within the ordinary range of tractive efforts exerted by railway motors, that the single-phase motor is so far deficient. In fact, it comes remarkably close to that of the direct-current motor.

Concerning the comparison between the 125-h.p. and the so-called 240-h.p. motor contained in the paper, I take issue, with the author. In my opinion the only reasonable way to compare the performance of single-phase motors with that of direct-current motors is to assume a car with a certain seating capacity, and then consider what equipment, alternating current or direct current, is suitable for this service. It is not fair to assume, as is done in the book by Messrs. Parshall and Hobart, a car of a certain total weight, carrying in one case fewer passengers than in the other. The object of a railway company is to accommodate a given traffic. It follows, therefore, that an equipment should be provided which will be serviceable. Motors should be selected on the basis of their speed-time curves and in accordance with their particular characteristics, rather than upon the simple horse-power basis. Further, it is unfair to take an isolated case of a single-phase motor which may be heavier than the ordinary and compare it with a direct-current motor which is certainly much lighter than ordinary motors of that capacity. If, in seeking to compare the two types of motors, the author had taken the 25-cycle, 75-h.p., single-phase motor referred to later on in the paper his conclusions might have been quite different. The weight which he assigns is 4199 lb. The weight of the corresponding direct-current motor is 3500 to 4200 lb. Moreover, if the single-phase motor to which he refers were operated on 15 cycles instead of 25, its output would be 90 to 95 h.p., which would lead to conclusions quite at variance with others in the paper. The weight of a quadruple equipment of

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90-h.p. direct-current motors furnished by the company with which I am connected would be approximately 20,000 lb. The corresponding weight of a quadruple equipment of 90 h.p., 15-cycle motors with oil-insulated transformers equipped for 11,000 volts would be approximately 27,500 lb., an increase of about 37.5%. This extra weight added to a 40-ton car would amount to about 10%. Owing to the greater efficiency in controlling single-phase motors, the power consumption of the car, including transformers, would in most classes of service be approximately the same as that of the direct-current motor at the trolley and would be much less at the power house. I wish to say, further, that a car for passenger service can be equipped with two 200-h.p., 15-cycle, single-phase motors giving ample clearance on 37-in. wheels, and that these two motors will operate a car with the same power consumption per car-mile at the car on runs as long as five or six miles as would be obtained with a car of the same capacity operated with an equipment of 200-h.p., direct-current motors. On shorter runs the relative power consumption would be less.

Now, concerning the use of high-voltage direct current. Motors can certainly be built to commutate satisfactorily on 1200 volts direct current. Such motors, however, must restrict the voltage between bars to a safe limit, and have extra space for insulation. The construction of this motor would therefore put it on a par with the 15-cycle, single-phase motor both in weight and dimensions. Moreover, it would have practically the same air-gap in moderate sizes of motors, and might possibly have to be designed with the same style of compensating winding on the field as is now used for single-phase motors. It would have in addition the disadvantage of a high voltage always present on the windings and brush-holders. If it were not for the greater possibilities of the single-phase system, there is no doubt but that the high-voltage, direct-current motor would be quite attractive. As it is, I believe that systems should be developed which offer the best solution for the entire railway problem. To attempt to develop a number of systems would result in not only scattering the energies of manfuacturing companies, but would retard the ultimate solution and supply the railways with a heterogeneous collection of equipments that would postpone standardization for many years.

G. R. Henderson: I am particularly pleased to find that the writer of the paper does not claim that electrification is a panacea for all railroad ills, but when applied to individual cases which have been intelligently studied and found to be suitable for such treatment, satisfactory results may be expected.

That success depends upon traffic density is made clear, and the importance of the load-factor is brought out, and I heartily agree with the assertion that trunk-line operation is vastly different from suburban service. As the two extremes, consider the New York subway, with constant trains at short intervals, and

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a division on a western road handling stock almost exclusively. There are one or two days a week when the stock must be brought to market, and perhaps from 12 to 20 trains will be run in one direction, possibly up-grade, at 15- or 30-minute intervals, as the market must be reached in time to avoid claims. Then for four or five days there may be nothing but one or two passenger trains and a local freight. Can any one imagine a railroad company rash enough even to think of electrifying its road in such a case? The power house and conductors would have to be proprotioned for the maximum traffic, but the average load-factor would not be ten per cent. Operating methods can no doubt be changed in many cases to advantage, in electric traction, but such traffic as I have referred to cannot be altered to suit transportation requirements.

The important factor of financial success is also brought out in the statement that unless a commensurate return on the increased investment can be assured, steam locomotives will not be abandoned. This item of first cost is an important one, when we consider that one horse power in steam locomotives costs about $10, and in power house, lines, etc., about $100. Electric locomotives themselves cost double the amount of steam locomotives, and as the average cost of coal in the Uinted States does not exceed $1.50 or $2 a ton, little may be obtained from fuel economy.

The great possibility of the electric locomotive in freight service (and this is usually the dividend-earning part of the traffic) seems to lie in the increased power available by small reductions in draw-bar pull corresponding to increase in speeds; but the relative value for each and every line can only be determined by making a careful study of all the factors involved for that particular piece of track. Comparisons with other roads may, therefore, be not only useless but positively dangerous, unless all the conditions are understood. These computations are laborious, but absolutely necessary. When we consider the different rates of pay and the cost of commodities in various parts of the country, and the effect of physcial conditions of the track, we realize the importance of careful analyses. By varying the train load we can run the cost of transportation per ton-mile to double the minimum figure, the charges for material and labor remaining constant, which shows how complicated will be the deductions from a thorough investigation of the subject, but unless so made they may be worthless. Characteristic power curves of both steam and electric locomotives would naturally form the basis for such a comparison, and these should be carefully laid out; and then by making combinations of diagrams representing the locomotive power and train resistance, the important fundamental advantages can be deduced for a variety of conditions.

According to the writer, regeneration is not promising as a method of reducing power consumption any more for electric

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than for steam traction, but it may reduce brake-shoe wear and lengthen the life of wheels. It could not replace the air-brake, however, for obvious reasons, but might be compared in its action to the Le Chatelier or Sweeney brake. Even air-brakes are now arranged so that they can be held upon the locomotive while re-charging the train on long grades, and retarded release is provided so that the rear-end brakes let go first.

I am glad to see that multiple-unit control is not considered feasible for freight operation, and that the great difference between this and suburban transportation is made clear. We heartily agree that it would not be wise to attempt to handle heavy trains on steep grades with one man, and the legislators would no doubt prevent it. The presence of a third man on locomotives of the Wooten type has often been discussed by our lawmakers, and the single man and multiple-unit control would certainly excite much opposition.

Having had twenty-five years' practical experience on railroads from the Atlantic to the Pacific, some of them operating on 3.5% grades over the Rocky Mountains, I cannot too heartily express my approval and endorsement of the very conservative statements and the sound logic enunciated in this paper; I believe that if these points are constantly kept in mind there will be few electrifications to criticise unfavorably, and that those who decide to abandon the steam locomotive will be able so to fortify their position with convincing figures and data that financiers will provide the funds and the results will justify the expenditures necessary for the work. While I do not expect to see the steam locomotive driven "off the earth", and am confident that for many years it will still be found performing most of the work of transportation in this country, yet I do believe that the electric locomotive is bound to increase rapidly in number and in favor, and that each in its own proper sphere, steam and electric traction, will coöperate to the advancement of transportation and the increase of prosperity.

William McClellan: It is to be regretted that the author has thought it wise to spend so much time comparing motors when it is well known that the single-phase motor is not equal in weight-coefficient or efficiency to the direct-current motor. From a practical standpoint the comparison should be made on the complete system from the coal-pile to the transported load. My experience in making comparisons of the several systems for different roads confirms the figures stated by those who have discussed the paper rather than the figures of the author. After operating an 11,000-volt, multiple-unit train under extreme weather conditions and heavy overload, it is a pleasure to report that the equipment is extremely flexible in every way and gives remarkably smooth operation. The control of motor voltages by the transformer taps seems to make for very smooth acceleration. The examination of the commutators with covers off showed, under heavy overload, sparkless or black commutation.

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Even when one of the cars was acting more as a locomotive than as a motor-car this was true. In these circumstances it is particularly gratifying to-night to learn that even better conditions can be expected from equipments produced now.

The author's paper spells the word "capacity." First, capacity of the truck for motors; secondly, capacity of the trackage for traffic. We certainly must all agree with the latter argument. There is little doubt that the electric motor can be introduced on steam railroads more easily by showing that the capacity of the ultimate trackage in a given locality can be increased more by electrifying than by any other motive power. It is probable that hundreds of miles of trunk-line electrification will be installed for this reason, before there will be sufficient information on the relative cost of operation and similar data.

It does not seem, however, that the capacity of the truck to receive sufficient motor power will ever be a serious menace to the success of the alternating-current motor, even if the present weight-coefficient is not improved. This objection obtains chiefly in connection with locomotive design. It should not be forgotten that almost all electrification so far has been in connection with terminal work where an electric locomotive must receive a train from a steam locomotive for a short run through a tunnel or otherwise. The more I study the problem, the more I am convinced that when we come to the electrification of a whole division, we shall depart from locomotive practice and turn to multiple-unit equipment. Even for through service it is more than likely that it will be found cheaper in the end, more elastic, and less liable to cause delays on the road. This has been forcibly impressed on me recently, while making some trial runs with new multiple-unit trains on a trunk-line division. Several times minor accidents happened which, had the motive power been concentrated in one unit, would have stalled the train for some time. With the multiple-unit train, however, it was very easy to cut out one car and make a run in without seriously disturbing the schedule.

Even in connection with freight traffic our present ideas may have to undergo a radical change. As we understand it now, receipts are per ton-mile while expenses are per train-mile. There is a possibility, however, that with electric operation we may be able yet to show that the quickest and least expensive method of getting freight over a given division is not always by means of the longest train and the heaviest locomotive.

In view of the fact that most of the engineers who are ardently expressing faith in the single-phase motor are at the same time advising the use of, and installing, 650-volt third-rail and overhead apparatus, it is a pity that there should be an opinion held that we are divided into hostile camps. Arguments comparing overhead construction with third-rail have been made so exhaustively and so frequently that there is little use here in repeating them. Since both are being introduced in various places we can afford to wait for time to bring out the truth.

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There are reasons, however, why, for trunk-line operation, opinion seems to be so strongly in favor of the single-phase motor: first, it is generally acknowledged that on account of expense and complexity of power distribution a 650-volt, third-rail installation, no matter how well done, will never solve trunk-line electrification. It seems evident that the case demands a high voltage, which in turn necessitates an overhead structure. If the present single-phase motor is not adequate or satisfactory, it must be improved or another type designed. If the present type of catenary construction fails in service, it may have to undergo radical change. In spite of these details, of the highest importance as they are, the general statement in regard to the system remains true.

Secondly, the electrical engineer must follow the engineer-of-way. The former must electrify whatever system of trackage the latter demands for moving his traffic. In large terminals and busy yards, unless present methods of switching can be revolutionized, the third-rail is not always available. I do not know of any extensive proposition where the third-rail has been adequate in such cases. The paper itself, though slightingly, refers to one large terminal where considerable overhead structure had to be introduced. This adds undesirable complexity to the car and locomotive equipments. In this connection it must be remembered that locomotive shoes will probably not span a gap much greater than 25 ft. This fact introduces troubles not met with in connection with multiple-unit trains.

Thirdly, every large road is a problem which must be considered financially on its own merits, but technically in relation to the whole system and to other roads with which it may come in contact. That system of electrification which may be most suitable for the operation of a large terminal may be one which it is unwise for the road to adopt, because sooner or later this may have to be extended to the whole system. Neither can the largest roads afford to ignore absolutely what other roads are doing in the way of electrification. The modern trend of enterprise is towards consolidation, exchange, and pooling. There is in process of formation, or perhaps already finished, a freight-car pool among the larger roads of the country; it is not beyond possibility that ten years from now may see a pooling more or less complete of passenger cars; and there is no doubt that many parallel roads to-day could adopt joint track agreements to the advantage of both and the great advantage of their patrons. It is these possibilities that a road must keep in mind when it starts to electrify, or it may later have to expend enormous sums of money to bring itself into conformity with a larger system of which it may become a part. Therefore, reasonable standardization is one of the things we should have on our minds all the time. No question should be decided without considering this point of view.

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A. H. Armstrong: It is very difficult for the writer to share the confidence expressed by some of the previous speakers as to the exact trend of future railroad engineering. This is an age of development. Things change over night and impressions formed last week are quite likely to stand in need of modification in the light of more recent developments. In this connection I may state that my impressions of alternating-current motor performance, which have been gradually forming as the result of several years' experience with such motors, have been very agreeably shaken by tests witnessed during the last few weeks.

I had an opportunity to witness a test on a 125-h.p. series compensated alternating-current motor operating at 50% overload. The commutation was excellent, as good as that of present direct-current motors, and was obtained by certain recent modifications in motor design and connections.

New developments are not confined to any one type of apparatus. The direct-current motor has exemplified this in the vast improvements made in the last year by the introduction of the so-called commutating-pole type of motor, which practically eliminates the question of commutation as a disturbing factor. Owing also to the development of the commutating pole, it is possible, with the better results obtained, to wind such motors for 1200 volts. The commutation of these 1200-volt motors is even better than the 600-volt motors hitherto used. It is, therefore, hard to predict with any certainty just exactly what field is covered by any one type of apparatus. We now have offered direct-current motors of 600 and 1200 volts that give practically perfect commutation, very high efficiency, and an adaptability of design that makes such motors applicable to a wide range of railway problems. We have also recent evidence that the alternating-current motor can be so improved as to approximate closely the present performance of the direct-current motor not having commutating poles. Such improvements must have considerable weight in determining the future field of application of this type of motor. I will say for the benefit of those that are anxious to standardize the frequency of 15 cycles, that the tests I have reference to were made at 25 cycles, and seemed to indicate that a thoroughly good alternating-current motor could be built without the necessity of adopting a new frequency with all the incidental complications involved in so doing.

Mr. Ferguson has expressed an opinion to the effect that the railway load in and around large cities like New York and Chicago represents only about 25% of the total electric power developed. in these territories. The use of 25 cycles is almost universal in and around large cities, and it would become a very serious commercial matter, owing to like conditions over all the country, if the future of the alternating-current, single-phase motor depended upon the adoption of a lower frequency.

I find myself repeating the advice given by Mr. Wilgus, to

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the effect that the electrification of our steam roads calls for cool, unprejudiced, common-sense engineering. Like him, I believe that the cause is injured by too strong enthusiasm for any one type of apparatus, and the best showing can only be secured by considering the type of apparatus best suited for the particular needs of the road in question as determined after a very careful unbiased investigation of the local requirements.

C. P. Steinmetz: I wish to endorse the statement that we are not yet ready to standardize one type of railway motor, or one method of electrifying steam railways. We shall not be ready to do so for some time; perhaps never. I agree with Mr. Wilgus that each railway problem should be considered on its own merits. The proper method of solving the problem in hand should be to apply the standard that has been found satisfactory by extended experience, and not deviate therefrom except where it is absolutely necessary. As has already been said, the problem before us is to substitute electric motors for steam locomotives where the conditions of service have grown beyond the capacity of steam locomotives. Whether the alternating-current or the direct-current motor has the advantage is rather a secondary question; the main question should not be lost sight of in discussing conflicting claims for the one or the other type of motor. At present there is an alternating-current motor and a better direct-current motor, regardless of the contention that the alternating-current motor is equal to the direct-current motor; for at the same speed and same energy input there is saved in the direct-current motor the power lost in commutating, and that lost as hysteresis in the field. The heating is less, and consequently the efficiency is greater. Now since the mechanical output or capacity of the railway motor is controlled by the heating, the alternating-current motor on a direct-current circuit gives the same mechanical output at a lower temperature; with the same temperature it gives a larger output.

There is a class of service where alternating-current motors are necessary—a long railway with infrequent and irregular service, and a considerable amount of fluctuating freight traffic—in short, conditions where synchronous converter sub-stations would show a poor load-factor. In such cases, direct-current operation appears impracticable, and here is the field for the alternating-current motor or the steam locomotive. Where there is a 4-track or a 6-track railway with traffic so heavy that the distance between trains is limited only by safe headway, the load on the converter sub-station is so nearly constant, the load-factor so great, the rapidity of acceleration required so considerable, and the maximum capacity of the motor so great that the advantage is decidely in favor of the direct-current motor. In such cases there is no excuse for using alternating-current motors.

I do not share the objections to the synchronous converter, and do not believe there is any gain in reliability in eliminating

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this link. It is an advantage in a system to eliminate some of the links, but what wants to be eliminated is the weakest link, and that is not the synchronous converter, but the motor. A synchronous converter is about the strongest link. However, between these two extremes there is a very wide field where either the alternating-current or the direct-current motor may be used, or rather where different engineers may be justified, impartially, in arriving at different conclusions; but what should be guarded against is the adoption of any one system which precludes one for ever from changing over to any other system. I refer specifically to the adoption of an arbitrary frequency. At present, after many years of work we have succeeded in eliminating all frequencies but the two now universally used—60 cycles and 25 cycles. At the present time all the heavy power of the country is transmitted at 25 cycles. Adhering to this standard frequency, it would not be so formidable a thing to use the alternating-current motor and then find that after all, the direct-current motor would be better. The alternating-current motor could be used for outlying side branches of a railroad and the main line be operated with direct-current; or, inversely, a start could be made with direct current and later changed to alternating current, provided the interchangeability of the system be not lost sight of. Herein lies the harm of radically changing the frequency. Compelling one to adopt a frequency of 15 cycles brings about a very serious condition; it means giving up the possibility of securing the benefit of interchangeability with the large amount of power now available at 25 cycles. In brief, 15-cycles would be an odd system, as odd as the 40-cycle system is to-day.

In regard to the 1200-volt, direct-current motor, my conclusion is that the commutation of this motor is so infinitely superior to the commutation of any alternating-current motor I ever have seen—except one—that there is no comparison. As Mr Armstrong has stated, there has recently been developed one alternating-current motor operating on heavy overloads with absolutely sparkless commutation. It is just as good as the standard direct-current motor, or probably a little better.

Frank J. Sprague: Owing to the lateness of the hour, I cannot now reply to the various speakers, because I cannot deliver my views in sufficiently condensed form. I shall have something to say later in a written communication to be inserted in the PROCEEDINGS. I think possibly the paper has at least one merit, it bids fair to bring out some additional facts about the apparatus of both kinds. The fact remains that a good many millions of dollars have been invested on two great trunk-line systems, which will soon be in competitive operation, and there will be a comparison on these roads which none of us can gainsay.

W. S. Murray (by letter): Conscientiously I find little in Mr. Sprague's paper to discuss. This was my conclusion at the meeting; the same now. It seems to me that what is not wrong

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in Mr. Sprague's paper is not new. In passing, however, I cannot fail to record here my high sense of appreciation for Mr. Stillwell's and Mr. Storer's excellent contributions, not so much because they were refutations of Mr. Sprague's unalterable conclusions, but for the valuable data they contained concerning the real relations in design and practice between alternating-current and direct-current railway motors. Again, it is difficult to express the pleasure in noting the small per cent. increase in weight for equal capacity and the almost coincident curve of efficiency. These cases being the citations of the chief engineer of the railway department of one of our large manufacturing companies, and a consulting engineer who has shaped the duties of many railway motors.

It would be my wish that the smallest emphasis be placed on the efficiency of the alternating-current motor, even though its efficiency curve throughout its complete range of load were the equal of its direct-current prototype. If efficiencies be considered, let us discuss the ratio of the pound of coal to the ton-mile. There is nothing electrical about this; it is within the comprehension of steam railway engineers (though it is a chain made up of electrical links); and if the ratio proves less for the alternating-current than for the direct-current system, then we have a real value that is of as much interest to the banker or director interested in the railroad as to the electrical engineer desiring its use. Would it not be better to consider the whole chain rather than one link? I welcome the new weights and the new efficiencies for their corrective (?) influences of the one-part-at-a-time man.

It was unfortunate that the photographs as originally shown in the advance copies of Mr. Sprague's paper were so poorly representative of the catenary construction. However, I am told these were the best the publication department of the Institute could produce on the very short notice they received. Those now published in the regular PROCEEDINGS are fairly representative.

T. J. Johnston (by letter): While I am quite willing to leave the discussion of the engineering features of Mr. Sprague's recent paper on methods of electric traction to professional engineers, it seems to contain (or perhaps to reiterate) an economic fallacy; namely, that the "financial factor" will determine whether a road shall be electrified, the implication being pretty plain that it, solely, will settle the question.

The process so graphically described by Mr. Sprague, by which our present enormous steam railway system was built up, is now going on before our eyes, with electric railways; that is, short lines of road are being built, cities are being connected, extensions are being made and eventually consolidated, until in many directions it is possible to take extended trips by electric lines. Awhile ago the writer rode in an electrically propelled sleeping car, the comfort of which may be imagined.

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The growth thus initiated will not stop short of a sufficiently complete system of electric railways; the willingness of present railway managers, or even their ability, to transform the power side of their systems need not be considered at all. If these gentlemen are unable to raise the money, they will be left with their freight business, and their passengers will be taken from them, even as now the interurban roads take all of the local traffic that is worth while, leaving the more expensive and troublesome long-distance trains as a sort of white elephant on the hands of the steam road. It will not be many years before the large cities will wholly prohibit the steam locomotive, as the Congress has practically done in Washington.

It is truly a serious situation for the railway men, with their credit hampered by foolish legislation and equally foolish popular clamor; while their electric rivals obtain privileges which no one would grant to the steam road. The problem of finding the money, and, after the money is found, of finding the available working force is truly tremendous, yet it must be solved. It is as certain as anything can be that our people want and will have electric traction on an increasingly great scale, until practically all of our passenger traffic at least is so operated. Nor will they be content with the present methods of running trains. It is amusing to see how a steam railway man with a converted road on his hands throws away the advantage of electricity and insists on running his cars in trains every two hours or so, instead of splitting up the units and running one or two cars every few minutes; for example, the Atlantic Division of the Long Island Railroad, upon which the flexibility of electric service is, during the "non-rush hours," nearly thrown away.

Lewis B. Stillwell (by letter): The paper read by Mr. Henry St. Clair Putnam and the writer on January 25 and the paper read by Mr. Frank J. Sprague on May 21 bring out an interesting and apparently radical difference of opinion in respect to the question of choice of system for electric operation of trunk-line railways. In the former the opinion was expressed that alternating-current equipment is the only class of equipment deserving serious consideration in connection with the general problem of replacing the steam locomotive by the electric motor on trunk-line railways. In the latter it is asserted that "where equal permanence of installation is provided for and equal ultimate as well as average duty there is not on demonstrated facts a wide variation in the initial cost of plant". While the position taken by the author is less radical than it was in the oral discussion of the paper of January 25, he devotes a large part of the present paper to the presentation of facts and opinions which have led him to the conclusion that the proposed 1200-volt, direct-current system is superior to the single-phase, alternating-current system.

When conclusions radically different are reached in a matter

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of this kind, the explanation is usually found by examining the premises respectively assumed. In this case an examination of the paper of the evening and consideration of certain facts clearly brought out in the oral discussion go far to explain why its author has reached a conclusion differing so widely from the opinions expressed by Mr. Putnam and myself.

1. It appears that the author's conclusions have been based largely upon a radical misconception of the facts as to weight and performance of single-phase, alternating-current motors as compared with direct-current motors. His reasoning is based largely upon the idea that motors of the former type weigh about twice as much as those of the latter type. As has been clearly shown in the discussion by the designing engineers of our great manufacturing companies, the difference in weight of 25-cycle, single-phase, alternating-current motors and 550-volt, direct-current motors of equal output is, in general, much nearer 25% than 100%; while the difference between 15-cycle, single-phase motors and 550-volt, direct-current motors of from 100 to 400 h.p. is still less.

The author places great emphasis upon the question of comparative motor-weights. If his view of the controlling importance of this consideration be accepted, it would appear that the reduction in the assumed ratio of weight upon which his conclusion so largely depends from 2 to 1 to 5 to 4, or less, might involve a material modification of his conclusions regarding the relative values of the contrasted systems.

2. It is evident also from the paper that its author has failed to balance accurately the inherent differences between single-phase and direct-current motors. In the light of Mr. Storer's oral discussion of this phase of the paper, the majority of the assumed disadvantages of the former disappear.

3. An apparent oversight may further explain how the author has arrived at his conclusion. I refer to the fact that his paper ignores the very important consideration that in general a protected third-rail cannot be located in any position upon the existing tracks of our railways which will not involve more or less interference with rolling stock equipment. The third-rail location adopted by the New York Central, for example, makes it impossible to operate over tracks thus equipped large steel coal cars of the type now so extensively used. The New York Central has met the situation by excluding from its tracks which have been fitted up with a third-rail certain classes of rolling stock. This special solution may be satisfactory in this instance, but in considering anything like a general electrification of trunk-line systems the interference of the third-rail with rolling stock constitutes a very strong argument in favor of overhead construction.

There is nothing in this paper, nor were any facts presented in its discussion, which justify a modification of the opinion which I have expressed to the effect that the alternating-current system

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is best adapted to trunk-line operation. The paper under discussion uses the 550-volt, direct-current motor in such comparison of alternating-current and direct-current motors as it presents, but in comparing systems substitutes the 1200-volt, direct-current motor for that of 550-volts. This substitution is materially easier on paper than it would be found in dealing with actual equipment. As a matter of fact, the so-called 1200-volt, direct-current system to-day does not exist except on paper; and while there is no doubt that it can be developed into a working system the paper under discussion ignores difficulties in the way of its development and application more weighty than any which to-day stand in the way of the complete development of a 15-cycle, single-phase system.

The New York Central has equipped its terminal with direct-current apparatus operating at about 600 volts, and has done so for reasons which probably were valid at the time the decision was made. It is conceivable that other railways in equipping terminals may be led by local considerations to adopt the same system. In the light of the discussion of this paper, however, it is difficult to conceive circumstances under which engineers would be justified in advising the use of 1200-volt, direct-current equipment in the electrification of a terminal or short division of railways now using steam locomotives. The author of the paper has advised the New York Central to use 600-volt, direct-current equipment in electrifying its New York terminal. He intimates that if called upon to do so he would advise the Pennsylvania Railroad to use 1200-volt, direct-current apparatus for the equipment of its line between New York and Philadelphia. Were this division of the Pennsylvania system to be electrically equipped to-day, it would be done for reasons which a few years hence will apply with almost equal force to the company's lines between Philadelphia and Pittsburgh. The present state of the art as evidenced by the facts set forth in the discussion of this paper and of the paper presented on January 25 justifies the statement that for the electrification of even short divisions the 15-cycle, single-phase alternating-current system at the worst is not inferior to the 1200-volt, direct-current system. The comparative advantages of the former, of course, increase very rapidly with decrease in frequency of service. Under conditions of average steam railway service in the United States, which were the conditions discussed in the paper presented by Mr. Putnam and myself on January 25, the first cost and the annual cost of the 1200-volt, direct-current system as compared with the single-phase, alternating-current system practically prohibits the adoption of the former. In view of these facts it would seem that there is no place for the 1200-volt, direct-current system in connection with the electrification of any part of our trunk-line systems. The 600-volt, direct-current system will do the work satisfactorily in electrifying a terminal. Only the alternating-current system is applicable, as the author

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of this paper himself suggests, to " roads of considerable extent which operate an irregular and sparse traffic ". Between these two there is no sufficient reason to justify the introduction of a third-rail system which does not pretend to solve the general problem, which can be used only on tracks from which certain classes of rolling stock are excluded, and which inevitably would introduce additional complication and interference with the ultimate standardization of electric railway equipment.

Frank J. Sprague (by letter): The comments on my paper have been varied and interesting, sometimes illuminating, but again marked by more of criticism than candor, and offering less of proof than affirmation.

I did not attempt to solve the problem of electric operation of trunk line railways, but rather to set forth some general problems, and certain technical facts as I have found them by somewhat careful investigation.

I have been taught by a modicum of experience that the electrical engineer is apt to approach the larger problem of railway electrification with a superabundance of confidence, undiluted with practical and necessary experience in that particular field. It has seemed necessary to utter a warning against too great a measure of self-reliance, too positive prophecy, and to indicate some of the difficulties in the way of achievement.

I prefer to deal with facts, not theories; performances, not promises; and where these are at variance, it is essential that the differences should be pointed out. I am, for special reasons, probably more anxious than most members of this Institute that railway electrification shall prove acceptable and beneficial, and I welcome every advance, no matter through what channel, which can contribute one iota to that end. So long as equal results are attained, it hardly seems necessary to emphasize the fact that simplicity is a desideratum of the utmost consequence, and I should be glad to eliminate every piece of apparatus between a central station and a motor which does not prove essential to operation.

If I express some measure of disappointment, it is because of the fact that in spite of all the work done, and my own hopes as well, more has not already been accomplished in the single-phase, alternating-current motor development, and that neither it—nor for that matter what has been done with high-potential direct-current motors—warrants approaching the general railroad problem other than with diffidence and hope, and makes us doubly obligated to urge the utmost progress along whatever path may offer any advantage whatever.

Whatever my beliefs, I cannot but chafe at the slowness of advance, and the subordination of development on the one hand to a fixed ambition, and on the other hand to commercial catholicism. I doubt if any member of this Institute questions how quickly and radically I would demonstrate my own confidence in future possibilities if the companies which have borne

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my name had not been swallowed up in the sea of modern consolidation, instead of my now being obliged to content myself with academic pleas for intelligent expansion.

Quite possibly I have not fully understood the purport of Messrs. Stillwell and Putnam's interesting paper, but if so, then I have company in such misunderstanding. While it is true we are not in entire accord, we are not entirely in disagreement; for I note that Mr. Stillwell accepts historical facts, and is even tolerant of my generalities. We do disagree, it seems, in one important essential at least. He has "nailed his flag" to a 15-cycle mast, guyed by an overhead trolley wire, for trunk-line service. I have gently remonstrated, and being something of an agnostic, have said "I don't know"—venturing the opinion, with which I am quite sure in the end most practical railroad men will agree, to say nothing of a large body of the electrical engineering fraternity, that no present standard can be safely adopted to the exclusion of everything else. Such a decision would be not only a bar to evolution in the development of the application of electricity to railways, but a final expression of opinion that invention is at an end, and that the dicta of engineers can decide or change the inevitable exercise of individual thought, and curtail the activities of competitive manufacture.

Mr. Stillwell lays much stress upon the "conditions of average steam railway service in the United States." The average conditions, measured financially, do not, in my judgment, permit of electrification, which conclusion I have tried to make clear, and which is not altered even if I have not succeeded.

I feel particularly indebted to Messrs. Wilgus and Henderson, the former of whom, in his executive position, has had immediate charge of a great electrical development, and both men of wide practical railroad experience, for their common-sense and illuminating comments from the standpoint of the steam railroad man, because our tendency as electrical engineers is to discuss with too much detail the technique of our profession.

Now and then in our art, as in all others, some one not too closely face to face with technical problems coins a laconic phrase, which one instantly recognizes as expressing the truth in a nutshell, and as a crystallization of his own ideas on the subject, and then he wonders why nobody thought of it before. Such a phrase, and a particularly apt one, is that of Mr. Wilgus', "evolution, not revolution". It is the concrete description of the progress in the electric railway industry since its beginning, and it is expressive of what it will be in the future.

In studying different motors, it seemed wise to expand previous methods, and to adopt one capable of wide application. Inasmuch as it was impossible within the limits of a paper already too long to apply this method specifically to all makes and sizes of motors, I contented myself with selecting one especially typical example of direct-current and 25-cycle, alternating-current motors, supplementing the details of this com-

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parison by some specific facts about other machines, namely, the smallest on regular interurban service, and the largest in present locomotive service, presumably a sufficiently wide range for illustration of certain facts, leaving the application of the specific method to any other case of interest to an engineer.

In comparing capacities, it is eminently proper that the *weight-efficiency* of electrical equipments should be based upon each of two conditions: first, the total weight of motors and any connecting device necessary to transmit the power of the motor to the axle, this weight, if the trunk frame forms a part of the motor, including such additional part as is necessary over and above that required for structural purposes; and secondly, the total amount of electrical apparatus as above determined, plus every device for collecting current or controlling the motors carried upon the car or locomotive.

Mr. Stillwell holds that I should compare motors of equal capacities, not of equal weights and dimensions, and states that since the weight-coefficients of all motors, of whatever make or type, increases with the size, there would not in such a comparison have been so great a disparity. Quite true, but the error of this reasoning is apparent if one reverses his proposal, and compares an alternating-current motor of a given physical dimension with a direct-current motor of larger physical dimensions and weight. What a disparity would then appear! I do not know that I am particularly surprised at the remonstrance which meets the actual comparisons made in the specific instance illustrated, for the method intelligently applied is sufficiently instructive for those who wish to know the facts to find further application. The meaning and the force of the comparisons will not be brushed aside by *ex-parte* statements of isolated and uncorrelated facts, or by such a criticism of specific motor weights and capacities as distinguished Messrs. Stillwell's and Storer's comments, somewhat unwarranted in view of my specific statement that the motors were "both standard modern machines".

In order to avoid any just criticism of the curves submitted, I selected not only standard modern machines of practically identical weight, but machines built by the same manufacturer, tested under like auspices and by identical methods, and by experts who had no thought that the machines would ever be compared in the matter I have shown. Not only are these machines of similar weight, but they are almost exactly of the same dimensions, of the largest practical size which should be put on a truck with a 33-in. wheel, and as large as should be used with a 36-in. wheel when running in the open on a standard railroad. Gear and transformer weights were, as stated, eliminated.

That an erroneous conclusion might be expressed in comments based upon a hasty and cursory perusal of a paper is understandable, but that it should be allowed to stand after opportunity to ascertain the facts suggests either great preoccupation,

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or a hiatus in memory. It is a wise father who is not ashamed of an adopted child, and I cannot but regret that Mr. Stillwell has so long failed to recognize, in motor *X*, whose weight, as well as speeds and capacities throughout a thermal range varying from two-thirds of an hour to five hours were given with exactness, a machine for which he is largely responsible. Its characteristics are based upon the official technical reports of the General Electric Company, the builders of this G. E. 69 *B* type for the Interborough Rapid Transit Company, on Mr. Stillwell's general specifications, 418 of these machines now forming part of the equipment of that road. They are sometimes "rated at 200 h.p. at 300 amperes", but actually test to 241 h.p. with 75° rise of temperature, according to the standard practice of the American Institute of Electrical Engineers. Several hundred more of these motors are in use on the London underground railways, and 268 motors of similar frame, known as the G. E. 69 *C*, built for 50 volts higher normal operation, nearly 100 less revolutions at the one-hour rating, but developing, notwithstanding, 232 h.p. with like rise of temperature, are in use on the New York Central Railroad. Type *Y* is the G. E. A. 603 25-cycle, alternating-current motor, and illustrates the largest of this type of machines built for motor-car work.

Call these machines what one will, by any name which may smell more sweet, the comparisons are on identically the same basis, therefore absolutely proper; and in all fairness comparisons of any machines should be made with identically the same kind of data. When so made, Mr. Stillwell's pyramid may be inverted, and landed on its base where it belongs.

A similar direct-current motor when equipped with commutating poles weighs about 400 lb. more, but in view of a remarkable freedom from sparking it can with perfect impunity be steadily operated at an increase of potential which will much more than offset the increased weight. As an example of what can be done with this type of machine, I have seen a standard motor of 75 h.p. commutator capacity, temporarily fitted with commutating poles, operated with an increase of 80% in voltage, and develop over 250 h.p. without a sign of distress. Of course this is unusual, and ordinarily prohibitive on account of the speed of the machine, but it illustrates the possibilities of an improvement which I have so steadily urged, and which is now being adopted has so largely augmented the allowable working direct-current potentials. If Mr. Storer will compare on the thermal basis a quadruple motor equipment of this type with an equipment of 25-cycle, alternating-current motors of like permissible speeds and weights, the comparison will be somewhat instructive.

With regard to 15-cycle motors, I enumerated with a good deal of particularity certain advantages which they individually offered as compared with the 25-cycle motor, and especially the increase of capacity. I assume there is here little room for

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disagreement; but granting the full measure of these advantages, variable in the matter of capacity according to the nominal rating, and the ratio of load to that rating, it seems quite apparent that the increase in weight of the transformer will largely offset the saving in motor-weight capacity. Inasmuch as we are concerned not alone with motor weights, but with the total weight which must be carried by the individual drivers, and within allowed wheel-bases, this offsetting of the saving in weight in one part of the equipment by an increase in the other cannot be ignored; and the question properly arises whether the advantages are sufficient to warrant the adoption of the standard in spite of many well known objections.

It is a curious commentary upon the futility of prophecy, that within a month of the announcement of the necessity of a new standard, and within the hour of its repetition, the responsible technical engineers of a great manufacturing corporation voice, not only for themselves but for a great portion of the engineering world, their disapproval of its adoption, and in the same breath announce a radical advance in 25-cycle motor construction which maintains the merits of a higher frequency, and removes one of the reasons for lowering it.

Comparisons based upon motors designed, but not built, are essentially unsatisfactory, and of course they will be more or less at variance, depending upon the size and make of motors selected. The 15-cycle, single-phase, alternating-current motor is too new a machine to have any record behind it. In my paper I compared the weights of certain standard quadruple motor suburban equipments, designating the motors A and B, the former for 15 and the latter for 25 cycles, the weights being those officially given by the manufacturers. These motors were of competitive makes, the former being the Westinghouse and the latter the General Electric, but, as I stated, I did not deem the weights given as final. It will be therefore perhaps interesting to know that, eliminating the element of competitive manufacture, and comparing recently given official weights of 15- and 25-cycle equipments made by the former concern, there is an excess of total weight of a quadruple equipment of nominal 75 h.p. motors greater than that given in my paper.

Certain features of the New York Central and the New Haven machines have been given so frequently that it is unnecessary to refer to them further at the present moment, except to state that their weight-coefficients are very different, and much in favor of the former machines. When large 15-cycle alternating-current, and other types of direct-current locomotives are built, there will be an opportunity to make further comparisons on a like basis. It may be interesting to note here that the recent decision to adopt three-phase locomotives on the Cascade Tunnel was because of lack of guaranteed capacity of 15-cycle motors.

Mr. Stillwell says that I do not pay sufficient attention to the

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cost of the intermediate link between the generating station and the locomotives. I will endeavor to add some information bearing on this point.

The New Haven electrical equipment comprises 35 locomotives weighing 93.3 tons each, or a total of 3266 tons. with an aggregate capacity of 35,000 h.p. on the hour rating. Considering the individual capacity, the number of machines which will be under repairs, the time in the shop and other lay-overs, I believe that not over 23 of the New York Central machines would be required to do the work of the 35 New York, New Haven and Hartford ones. The New York Central locomotive weighs 95 tons, which will make a total of 2185 tons, with an aggregate capacity of 50,600 h.p. The difference in total weight is 1081 tons, and on an assumption of an average duty of even 200 miles per day there would be an excess of 216,200 daily locomotive ton-miles on the New Haven system. The difference in the cost of the above locomotives would ordinarily be about $400,000. The total distance from Stamford to the Grand Central Station is 33.48 miles, 21.45 miles comprising the single-phase section. As I have pointed out in my paper, the direct supply to the overhead line from the main station is but a special provision; it does not mark any wide application, for step-up and step-down transformers will be absolutely necessary as a general rule. Therefore, for comparison, we may assume on the New York, New Haven and Hartford the presence of those transformers. The introduction of synchronous converters in addition, assuming the same number of sub-stations, would add about $15 per kilowatt of normal capacity, so that the $400,000 differential in locomotive costs would provide for a synchronous converter addition of 26,667 kilowatts, which would have a temporary excess capacity of anywhere from 100 to 200%, according to the specifications of the engineer and the zeal of the manufacturers.

But this is not all. In a letter addressed to Mr. W. H. Newman, president of the New York Central, under date of Oct. 27, 1905, and published in the technical press in December of that year, in which the abandonment of the system then being introduced, and the adoption of the single-phase alternating-current system were urged, one of the principal reasons given was a great saving in cost of the working conductor system, which it was claimed would aggregate $9,000,000 between New York and Buffalo on the Central's line alone. The actual difference in the number and cost of equipments which would be required was ignored. The estimate per mile of road of a four-track line, with catenary construction from bridges over the tracks, and with operation at 6000 volts, exclusive of transformers, was given as $12,436. Some time afterward an estimate was published purporting to give the cost of the New Haven installation, which with additional provision of an extension of the bridges to cover six tracks instead of four, but not including the additional overhead work, was stated to be $27,000 per mile of road, although with operation

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at 11,000 volts. A careful analysis of actual construction makes this, according to Mr. Wilgus' statement, probably over $50,000 per mile, which I assume is exclusive of any lowering of tracks, clearing of right-of-way from trees, or work in connection with telegraph or telephone circuits. The cost of the working conductors of a third-rail system for four tracks, the protected under-contact rail being used, supplemented by a main conductor so that any of the tracks can be cut out, is much less than this.

Looking into the matter soberly, then, it would seem that in the first really comparative examples on a large scale, the cost of the working-conductor construction of the alternating current system as actually erected is considerably higher than that of the third-rail construction, when installed on a trunk-line railroad in operation, and also that the cost of equipment to do equal work is much higher, this latter difference alone being enough to pay for a great abundance of synchronous converter apparatus.

Just here, I may be permitted to suggest that it savors of trespass beyond the proper limits of a discussion of my paper when one assumes what my decision would be in the event of my opinion being asked as to the equipment of a trunk line division. Whenever such decision may be necessary, it seems reasonable to suppose that I shall be guided by the particular railroad problem under consideration, the real interests of my clients, and the then known or probable development in the art, quite irrespective of what my decision might have been at some other time and under other conditions.

It seems necessary to emphasize the meaning of restricted capacity of equipment for any allowable truck dimensions and unit wheel-weights. I repeat that it is a matter of no vital concern that 20 or even 40 tons be added to the weight of a freight train with any given motor capacity, especially on low-grade roads; but it is of the utmost importance if either the same capacity can be got with fewer units, or if, on the other hand, the excess weight will give even 50% more continuous capacity. What is required in any locomotive is simplicity and capacity; simplicity, to avoid an acute attack of appendicitis when far from home, and capacity, to meet the inevitable overload demands which will be made upon it by the operating force and the exigencies of service. This latter quality has been the constant aim of every superintendent of motive power, every general manager, and every locomotive builder. Larger cylinders and boilers, increased tube and grate surfaces, and more capacious fire boxes—all demanding greater weight on wheels, continually opposed by the limitations of bridges, rails, and ballast, and disheartening to the engineer of maintenance and way.

Need there be any more eloquent and forceful, nay, vital plea for keeping down wheel-weights, both individual and as concentrated on bridge members, especially when running at high speeds, than the appalling number of rail breakages reported during the past winter, and the recent attack upon the

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sufficiency of rail-sections and the integrity of rail manufacture—all emphasized by the Carnegie company's report of 20 broken rails after a single trip of the Pennsylvania's 18-hour flyer to Chicago!

On the subject of costs, we should be somewhat chary in formulating conclusions based upon assumed prices for electrical apparatus. At a former meeting of the Institute, unit and differential prices were given for 15- and 25-cycle electric locomotives. Mr. Stillwell based his calcluations on $25,000 per locomotive for 25-cycle operation, with a possible reduction of $1,000 for 15-cycle equipments, this latter difference being enlarged to $5,000 per unit by Mr. Storer. Little reliance can be placed upon such figures when it is well known that for various causes, such as changes in price of labor and material, variation in types of motors and locomotive design, the use of alternating-current or direct-current apparatus, etc., the unit price of various locomotives within the last three years has varied, not $1,000 or $5,000, but over $25,000, and the actual capacity of the highest priced locomotives has been less than that of lower priced ones.

Mr. Storer has favored the discussion by several positive statements, and certain figures giving the capacities and efficiencies of various types and sizes of motors. As presented, these are interesting but not conclusive; I submit that it is impossible properly to discuss them unless sufficient data are given to analyze them on the thermal basis after the manner I have indicated. There is nothing mysterious about it; and if in addition to the thermal curves, there are submitted the detailed statements of the weights of apparatus which go on a car or locomotive, we will be in possession of that much needed information urged before the standardization committee of the Institute as essential to a full understanding of machine performance. Engineers need the facts, but they should be complete, not such selected ones as manufacturers are sometimes inclined to submit for digestion.

Reference to the relative torques attained by continuous and intermittent currents is unfortunate, for if there is any characteristic of single-phase operation which is particularly noticeable, it is the slow acceleration of cars equipped with such motors; in other words, the lack of motor torque with equal gear reductions. The reasons are too well known to waste time discussing them. Mr. Steinmetz very aptly puts the case in a nutshell when he states that no matter how good a single-phase alternating-current motor is, when put on a continuous-current circuit it is a better motor, and it then becomes possible to re-design a machine to get more capacity out of a given weight, or less weight and less cost of construction for a given capacity. Possibly the self-repairing characteristic of the motors referred to by Mr. Storer may be explained by the fact that, weakened by an alternating current, they broke down when put on to a grounded circuit, and when put on to a lower potential metallic circuit they managed to function.

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It is a new theory in mechanics that reduced clearances and allowable wear of working parts is preferable to ample latitude in these matters. With regard to gears, it is quite possible that on the motors with which he is acquainted the same gear-pitch is used on slow-speed direct-current motors and high-speed single-phase motors. It might occur to one that permissible strength of parts in one case is sacrificed to the manufacturing requirements of the other.

I confess to a stenographic error in the matter of the minimum number of poles on single-phase motors. Of course, most people know that four instead of eight poles are used on certain sizes of motors; but there are other manufacturers, and 14-pole machines have been proposed.

It is quite true that locomotives are not intended to stand still—Mr. Storer remarks that they are intended to move. Undoubtedly, but it is likewise necessary to start a train, or perhaps hold one on a grade, and there are times when a machine, if a part of the equipment fails, may be called upon to stand very considerable periods of steady pulling without actually turning, and certainly great overloads. A little greater familiarity with practical railroading would perhaps show him instances in which locomotives are really not intended always to go, but sometimes actually stand still and push, and keep on pushing. A case in point is the operation of freight trains on long up-grades, where the helper locomotive, well back from the head of the train, is frequently called upon, when the leading locomotive pulls up on signal, to hold the train with full head of steam against slackened draw-bars, and to prevent it being pulled in two when the leader starts again.

It will not do lightly to dismiss the New York Central type of machine from further discussion, or possible notice, by remarking that there is but one single installation of this type. That is quite true, but it happens to be the largest electric locomotive installation in the world, and this particular group of machines is now probably doing more work than all other electric locomotives of trunk-line size which have been built in the United States in the last twenty years. It is, therefore, a machine which must be seriously reckoned with.

Mr. Scott seems to favor alternating-current braking by return of energy to the line, and even claims it to be more effective than direct-current braking on a closed circuit. His present attitude on the subject is a reversal of position assumed but a short time ago by his associates; but this is in accord with the change of heart on multiple-unit operation and commutating-pole railway motors.

In referring to the discussion of Mr. Carter's paper before the Institution of Electrical Engineers, I did not state it as a fact, or my opinion, that there is 10% lower electrical efficiency in a single-phase motor as compared with the direct-current current motor, but quoted Mr. W. M. Mordey, a well known

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advocate of single-phase apparatus, and for the purpose simply of illustrating the fallacy of assuming that the location of the excess loss, no matter how much, is a matter of indifference.

Of course, as Mr. Scott says, by varying the voltage taps on a transformer, the speed with any given torque can be reduced below that corresponding to the maximum working potential. I might add that the capacity is reduced in the same ratio, and there would be little effect upon the comparison of weight-co-efficients.

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Discussion on "Lightning Phenomena in Electric Circuits", "Protection Against Lightning, and the Multigap Lightning-Arrester", and "New Principles in the Design of Lightning-Arresters", at New York, March 29, 1907.

F. A. C. Perrine: Dr. Steinmetz gives a clear description and classification of the lightning phenomena that aid us greatly in understanding the problems and the methods proposed for meeting them. They are, however, the simple problems; there is yet to discuss what occurs when two sets of waves started from different points on a long transmission line eventually come together. Aside from the increased constants (capacity and self-induction) I think there will be additional difficulties, due to the fact that in a long-distance transmission line traversing a great area there may be a storm at a certain part of the line and clear weather at another part; or there may be two independent storms in different parts of the line, giving lightning effects which induce waves that meet and combine, and increase the effects. Otherwise there would not be so much difficulty in protecting fairly well a long and extensive low-potential distribution system.

I am inclined to disagree with Messrs. Rushmore and Dubois in regard to the horn arrester. The real theory adopted by those who have used the horn arrester is largely left out of this paper. The horn arrester, where used successfully, has been used on the principle that the wave trains which Dr. Steinmetz has been explaining do not in themselves produce potentials that will break down the insulation of high-potential lines. The principle is that money would be better spent in erecting lines so as not to make the insulation subject to breakdown by wave trains of relatively low potential, such as would have to be guarded against in lower potential lines. The horn arrester is introduced with the idea of saving the apparatus from destruction where any other form of arrester would not itself be destroyed, and even if protected, the machinery would lie open for damage in the further continuance of the storm. This is a condition frequently met with in the introduction of the multigap arrester even of the best form. With extreme cases, which Dr. Steinmetz has described, of the short-circuiting potential and discharge across the arresters of extraordinarily high energy, the multigap arresters generally fail and the line is then left unprotected even if the machinery is safe.

At a recent meeting of the Institute, in referring to the lightning-arrester problem, if I remember correctly, Mr. Mershon said he used three sets of horn arresters each of a different value of resistance in series. That system has had, say, a year of operation at Niagara Falls. While it has demonstrated that the system of protection is not complete—requiring for certain types of discharge that come from the line a set of multigap

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arresters in connection with the horn arresters situated probably inside the station—yet the horn arresters will discharge over the multigap arresters, and these high-frequency discharges are discharged over the multigap arresters harmlessly. At the same time the horn arresters discharge the low periodicity surges which are usually destructive to the multigap arrester.

I do not agree with Mr. Rushmore and Mr. Dubois that the horn arrester is better adapted for discharging high-frequency discharges. As a matter of fact the opposite is true. As stated by Mr. Creighton, the higher the frequency of the discharge the more rapidly is it carried over the multigap arrester. The low-frequency discharges are not so well taken over the multigap arrester, whereas with the horn arrester the low-frequency discharge is more rapidly taken over than with the multigap arrester.

In the present state of the art, excluding the electrolytic arrester described in one form to-night and in another form by Mr. Jackson a few months ago, I think the best protection is a combination of the horn and multigap arrester; the multigap arrester to take charge of the relatively high-frequency discharges, and the horn arrester to take charge of the low-frequency discharges.

I think that the construction of a polehead to take care of the overhead ground wire is open to criticism. In the first place, the pipe is an extremely bad piece of engineering. The connection to the pole is not good, for the amount of leverage shown is excessive; and I confess that for the present I cannot see how a workman is going to attach a ground wire, $\frac{3}{8}$-in. in diameter to the top of the pipe, unless there is some means provided for hauling up the wire to prevent the dead-end from being pulled over.

As regards the guard-wire put on the arm, as a horn arrester to protect the insulator, I cannot see how that particular form of arrester will do other than hold the arc. If an opposite horn were brought out from the line, and a horn arrester made there, it would discharge and protect the insulator In the same connection the authors speak of the specification for this overhead wire. I have always believed that a barbed wire, if made properly, is a better means of line protection than a smooth wire; at the same time I question very much whether a satisfactory barbed wire arrester can be made. I prefer a three-wire $\frac{1}{4}$-in strand of high grade steel to a $\frac{3}{8}$-in. stranded steel.

The treatment of the multigap arrester adds to our knowledge of the manner of action of this bit of apparatus. Mr. Creighton explains particularly the influence of the rectifying effect of the non-arcing metal (to refer to Wurts' term). The capacity effects described in the paper by Messrs. Rushmore and Dubois are simply in addition to the effect of the series resistance or shunt resistance, and in addition also to the rectifying effect of the metal in the

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gaps--and metal which will rectify is absolutely necessary for the success of the multigap arrester. Mr. Creighton explains in an interesting way the function of the resistance in connection with the multigap arrester. He calls attention to the fact that there is really no radiation from the resistor in such an arrester; and in forming such resistor there must be taken into account the specific heat of the material and the extent of the metal, so that it may absorb the energy. At this time, and I believe for the first time, our attention is called to the fact that the radiation of the resistor is relatively unimportant.

We seem to have here an entirely new form of electrolytic arrester. The principle Mr. Creighton describes is of actually striking an arc in the electrolyte, and so obtaining the benefit, as a resistance, of the counter electromotive force of the arc is very important indeed. We all know what Edison said of his storage-battery: "The damned thing is wet." This apparatus is not only wet, but it relies for its action on the formation of an arc within the arrester, which I should suppose would very rapidly evaporate the electrolyte, and the cells would require considerable watching in order to keep the electrolyte at a certain level.

As Dr. Steinmetz has aptly said, lightning-arrester problems cannot be efficiently studied in the laboratory. At the same time our somewhat restricted methods of work in the laboratory can better be explained and extended to practical use by means of the oscillograph than by any other means. The laboratory work on the electrolytic arrester of Mr. Creighton is of great importance, particularly because he shows his arrester as a single-gap arrester; in other words, a horn. At the same time he shows how the horns can be set close enough together so that they will take care of the high-frequency, low-potential discharges as well as the low-frequency, high-potential discharges; this gives practically a single horn arrester with a variable resistance in series, which is all that the horn arrester needs in order to become the best arrester that can be made. Furthermore, the electrolytic arrester puts what amounts to practically a variable fuse in the circuit, as well as a variable resistance, and it gives also a replaceable fuse. In my mind the need of the fuse is the greatest criticism that can be made of the arresters shown by Mr. Rushmore. All these arresters have fuses in them. If they are meant to blow, I feel quite sure that all operating men will agree that in a serious thunderstorm, such as occurs in the South or in the Colorado region, they will never be replaced after they have once blown during that storm. I do not know of any man with nerve enough to go near an arrester to put in a new fuse.

This substitution of a variable resistance, counter electromotive force, and a replaceable fuse and single gap arrester which is described by Mr. Creighton, is, in my mind, the practical solution of the lightning-arrester problem. I believe if this is

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worked out commercially we will be much nearer the complete solution of this problem than we have ever been before.

Farley Osgood: I will not attempt to discuss the papers individually, but will endeavor to contribute some corroborative evidence concerning the problem as a whole. Experience seems to show that lightning protection is an individual study for each individual plant, and for each individual locality. In talking with other operating engineers, I find that they use quite different methods of protection from the ones we use and they are equally successful or unsuccessful. Each man seems to have his own ideas about it, so I think that the lightning-arrester problem, like some of our other problems, is going to be a rather difficult one to standardize. I do not think the difficulties of atmospheric conditions are so very serious, generally speaking. Dense fog causes most of the trouble to our outside system; during other times we seem to get along without difficulty.

I will now relate some actual experiences occurring in a 33,000-volt transmission system, of 60 miles, carrying three substations, with power and lighting load, and 60-cycle synchronous converters. The multigap arrester with the resistance in series with the gaps, was used in 1904 and 1905, and was finally given up because the series resistance sticks broke and the protection was lost. The next year we took up the multigap arrester without the resistance sticks in series. This arrester, as can be seen from the photographs here, was very easy to adjust by changing the units to be shunted and changing the resistance of the shunt. We started with 14 units of 24 gaps each, shunting three units with 14 sticks, 250 ohms per stick. This equipment was gradually reduced until we used 10 units, to the multiple connection between the phases, and ten units below the multiplex, shunting 5 units with seven 250-ohm resistance sticks. We found by the tell-tale papers that with seven 250-ohm resistance sticks the current would seldom pass through the shunt resistance. We reduced them to five and then found that we got at least half the discharges through the shunt, sometimes more. This arrester, adjusted in this way, has been successful. It takes light discharges without the slightest difficulty; it takes moderate discharges with but very little difficulty; it takes very severe discharges at times, but these severe discharges are apt to cause the cylinders of the arrester to weld together, which of course puts the arrester out of service.

Another thing that has been noticed is that the discharge is more frequently line to line than line to ground. The 1906 record shows that we have taken in some storms twenty discharges without an interruption to service, our time-limit breakers being set at six and a half seconds. We have taken 17 discharges without interruption, the eighteenth discharge opening the breaker. I could cite case after case of storm in the surrounding country, but not directly on the system,

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where there were intermittent discharges between the phases to the extent of fifteen, or even as many as twenty-five in the course of two or three hours, without the slightest indication of interruption. This is the best record we have been able to obtain with protective devices.

Mr. Rushmore and Mr. Dubois speak of choke-coils. We have found them very effective, and consider that they are a great protection to the high-tension bus-bar insulators. A 20-turn coil 6 in. in diameter made of 00 copper seems to answer our purpose fairly well.

Dr. Perrine objects to the electrolytic arrester on account of its being wet, but I see no reason why it should not be made water-tight.

I do not wish to talk very much about Mr. Creighton's tests, although it was my pleasure to be present at the time they were made. I can simply corroborate what he says, that some 40 arcs, five feet in length, were drawn by grounding one phase wire just ahead of the liquid arrester. The multigap arresters just described, the record of which just given shows that they are very sensitive, were in parallel with the liquid arrester. Not once was there any apparent discharge on any of the units of the multigap arrester. These tests were made with 30 miles of circuit cut in.

Dr. Perrine speaks of the length of the transmission line having a great deal to do with the matter of protection. That seems to be true. In our experience we found wave peaks developed between stations, which do much damage before the arresters at the ends of the line begin to help out. We installed what we call our midway arrester, a multigap installation about 10 to 12 miles from the power station. Immediately after this was put into service the constant static discharge on the power station arresters and the sub-station arresters was cut down nearly one-half, and the constant static discharge at the midway arrester was greater than at the generating station or at any of the sub-stations. That seems to be fairly good proof that arresters on the line are a good thing. For the benefit of other operating engineers, I might state that this arrester equipment is very near the patrolman's house, so that it is easily controlled.

One great trouble in following the study of arresters is to get definite information concerning the action of the arresters. We do our best with tell-tale papers, but it is very often impossible to replace a tell-tale paper after a discharge comes, for another discharge comes so soon and operators have other things to do besides watching the arresters. Our tell-tale papers burn up during severe storms, and this destroys our records completely. I would suggest that a tell-tale paper which would not take fire but which could be prepared to show a puncture, would help us to obtain better records. It is a difficult matter to get the operators to realize the importance

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of following every lightning storm, to the extent of counting the number of discharges, but if proper forms are made for this purpose I see no reason why the study cannot be carried on without great difficulty.

The worst operating condition we have to meet is that due to grounding. More damage is done when a phase grounds than at any other time. I am not prepared to say that grounds only are responsible for the destruction of apparatus, but more apparatus is destroyed when there are grounds than at any other time. Mr. Creighton's liquid arrester, which was connected for the protection of grounds on the system, apparently solved the problem completely. The development of the liquid arrester brings out the fact that at least for grounds it may be necessary to have arresters only at the generating end of the system, or at least at the extreme ends, with no equipment in between. The power of self-restoration of the electrolytic arrester is one of its most beneficial qualities.

P. H. Thomas: It is interesting to note that most engineers are in agreement in the matter of protecting apparatus from damage by lightning. The multigap arrester with shunt resistance, ignoring the electrolytic arrester for the present, seems to be the most promising direction in which to work. The differences in commercial designs now are comparatively small.

In general I agree with nearly all that is said in these papers, but there are some things still open to an honest difference of opinion. Unfortunately, it is necessary to emphasize the things we do not agree with, even if they are not so important as some things we may approve of.

I do not know that I agree with Dr. Steinmetz's new definition of lightning. We must of course recognize the fact that an arrester is not only effective, if it is effective at all, against lightning, but also against the other sorts of static disturbances; but if we want a general term, rather than change the time-honored significance of "lightning," I would suggest the word "static," which has been pretty generally used. Another thing which does not appeal to me is the analogy that Dr. Steinmetz makes between electrical wave phenomena and the surf of the ocean. The reference to surf presumably means the dashing of spray which results from the pounding of the water against a surface, either the horizontal surface of the beach, or the overhanging surface of a rock. As we all know, in the electric circuit capacity is analogous to the spring or to elasticity; that is, the freedom of the water of the ocean to move upward in the analogy. Self-induction is analogous to inertia. The analogy of the splashing of water, where it strikes *against* an opposing surface, is the breaking, or instantaneous stoppage of the flow of current; it is in the nature of the Wehnelt interrupter, or the low-tension break in a Rhumkoff coil. The phenomenon in a transmission line, when a wave meets a reflecting point, is truly analogous to the

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wave in the water reaching a perpendicular smooth wall; the wave will rise to double the height, but there will be no splashing—a plain, simple vertical rise. If the wave be in a trough of water, and the trough tapered off to a point, and the taper commensurate with the length of the wave, there will be a rise of potential, but not a splash; a normal, straightforward rise. There is evidently no break in the continuity of a transmission circuit on the reflection of the electric wave.

I am more inclined to agree with Mr. Rushmore than with Dr. Perrine in connection with the horn type of arrester. I think we are far enough advanced to protect our apparatus without the very annoying disturbances of shutting down the plant. The grounded wire is certainly some protection, but, as Mr. Rushmore says, not complete protection. One of the difficulties, even if the wire is placed directly overhead is that the discharge which strikes the line is more apt to come from the side. Coming thus, it approaches one of the side wires before it does the grounded wire, and there is frequently recurring on these lines alternately positive and negative potential, which will tend to draw the discharge to one of these wires from the ground wire. It is often suggested that a grounded wire, if it be grounded frequently, will act effectively in reducing the severity of discharges, on account of the short-circuiting secondary action. It does not seem to me probable that the effectiveness of this action will be at all considerable, and for this reason—to produce any corrective effect the reaction of the induced current on the primary circuit must be considerable. Take an ordinary static transformer, where the reaction of the secondary on the primary is virtually perfect. To accomplish this result it is necessary to have an iron core and the closest relationship between the primary and secondary windings. In the constant-current regulating transformer, where there is provision to separate the windings, if the coils are close together, there will be a nearly perfect relationship between the primaries and secondaries, and a nearly perfect reaction of the secondary on the primary. But if the secondary is separated from the primary, the effect of the secondary on the primary is almost negligible.

In his admirable discussion of the principles covering the discharge through a series of gaps, there was one thing Mr. Rushmore did not take into account, and that is the fact of the leakage of current over the surface of the insulator between the cylinders. This will tend to distort numerically the conclusions reached. If this phenomenon gives trouble in designing arresters, it is easily controlled by placing a considerable gap in series with the arrester, between the lines and the first cylinder. or by using a shield connected to line. A great deal of stress has been laid on the fact that in virtue of the resistance adjustments the arrester Mr. Rushmore has designed will not break down on lower voltages at high frequency, than

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at a low frequency. Offhand, I do not see why if a high-frequency disturbance will go to ground more readily than a low-frequency disturbance, it should not be permitted to do so. If this resulted in a too frequent discharge of the arrester, it would be harmful, but our experience does not appear to indicate that such is the case.

The term "rectification of vapor" has been used several times to-night to explain the non-arcing property of a multigap arrester. The significance of this term I cannot quite understand. Vapor consists presumably of an aggregation of atoms or molecules, and since the atoms or molecules move freely in an entirely accidental manner, I cannot understand how this vapor of itself can have any directive effect. I think the action can perhaps be explained in the following manner: it is pretty well agreed that an arc starts by the ionization, through potential strain, of the gases between the electrodes, by which ions are liberated. They are then forced to move extremely rapidly by the high potential and produce other ions, until finally there is such an increase of temperature and such an increased ratio of ionization, that the quantity produced is sufficient to carry the normal arc current at a low voltage.

It is now easy to imagine in these narrow gaps between large cylinders in the multigap arresters that when the discharge comes along, ions are produced in this way, but that the instant the discharge and normal current ceases at the end of an alternation, in view of the close neighborhood of the conducting cylinders, the ions which would otherwise hold over until the return of the voltage are freely absorbed by the metal. The fact that an easily vaporized material is used in the composition of the cylinders will keep down the temperature; and since ionization is very closely related to temperature, the high temperature very much increasing the ionization, this effect will account for the properties of different materials. The current is of course carried by the movement of the positive ions to the negative pole, and the negative ions to the positive pole.

I would like to ask Mr. Creighton whether in his tests the results are based on anything more than the work with the 2300-volt outfit described here? that is, whether higher voltages or larger powers were used?

E. E. F. Creighton: We have taken some measurements at higher voltages, but we have not made as complete a study of them as in the case of the 2300-volt machine.

P. H. Thomas: The question of power behind the tests is absolutely of importance in this sort of work, and inherently the higher the voltage the more difficult to handle. Personally I should be very skeptical of the general non-arcing quality of this arrester without series resistance, and unless there are other data than what appears here, I should not suppose it would be safe to infer anything as to its general non-arcing

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quality. We find in one of the oscillographs, Fig. 4, that 200 amperes absolutely cuts the generator voltage down from 2,000 to a few per cent. of this value, showing a very limited capacity of power behind the arc. Similarly with Fig. 5.

V. G. Converse: Having installed at the plant with which I am now associated a considerable equipment of horn-gap arresters, I may perhaps be expected to take exception to the comments made in Mr. Rushmore's paper regarding this arrester; on the contrary, I quite agree with him. However, Mr. Rushmore states:

> Where a fuse is used in series with a horn having no resistance, it can, of course, take but the one stroke, and after this the system is unprotected.

This objection can be overcome by the use of repeating fuses arranged so that if one fuse blows, a switch drops, connecting in a second fuse; if the second fuse blows, a third is connected by a switch, and so on. If the fuse is of a proper enclosed form, it in itself very nearly meets Mr. Rushmore's requirement for the ideal arrester; but such a device may not be termed a horn arrester as the horns are no longer necessary.

Mr. Rushmore further says:

> The real function of the horn arrester is its use to protect insulators along a transmission line, where the horns are so arranged that the current will jump to the horn before it will arc around the insulator. In this case the system would be disturbed either way. Where it is allowed to arc around the insulator, the latter would probably be destroyed and the time of disturbance of the system might be considerable —possibly until the insulator is replaced. With a horn protecting the insulator, the resulting short-circuit, while very undesirable in itself, is less disastrous than in the former case, and may only necessitate starting up the synchronous apparatus again.

From my experience, and I believe that it will be found to be the experience of others, the principal lightning troubles on a high-tension system are stated in those few sentences. The Ontario Power Company during the whole of the last season had only one discharge of consequence over its arresters at the generating station, but had a considerable number of discharges along the lines, which caused interruptions of service.

The lightning-arresters described in these papers are essentially station arresters, and while it is gratifying to learn that satisfactory results are promised for this purpose, it should not be overlooked that for continuous operation, line lightning protection is also of great importance, for which other arresters are required.

D. Dubois: In regard to the breakdown of the high-voltage arresters at a low-frequency power surge, a little more should be added. As the voltage rises, and before it reaches a dangerous value, the gaps G_5, Fig. 3, arc over. As explained, the voltage to break down these gaps must be higher than if no resistance were used in series. With these gaps broken down, the current of the arc across them is limited by the high re-

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sistance to about $\frac{1}{16}$ ampere, which gives about 80 volts drop per gap. The remainder of the voltage is consumed in drop across the resistance rods and is thus applied across the gaps G_h. Although this voltage is less than that which broke across G_s, the series resistance is less, and approximately the same number of gaps will therefore break across at this lower voltage. With G_s and G_h broken down, the increased current gives a smaller drop in the gaps, but twice the number of arcing gaps are now in series. Therefore the number of gaps in G_m is made the same as in G_s and G_h. These three sections should all arc over in succession at very nearly the same voltage.

In this arrester the different kinds of lightning will follow different paths through the arrester, and test papers should be more useful than ever before in determining the nature of the discharge. Test papers should be placed in all four divisions of each line leg, and in the three divisions of the ground leg. Designating the different divisions as in Fig. 33, G_s, G_h, G_n, etc., the different kinds of lightning should produce punctures and burning as follows:

Static charge of the line relieved or a very light discharge—G_s small slightly burned pin-hole, others not touched.

Low-frequency surge of small power, or discharge of medium frequency—G_s and G_h small burned holes, others not touched.

Low-frequency power surge, or abnormal rise of power voltage—G_s, G_h and G_m well burned holes, G_1 not touched.

High-frequency discharge of the arrester—G_s and G_h small burned holes—G_m and G_1 punctured, but not burned.

The test papers of the ground leg can show whether the discharge took place from line to line or from line to ground, and whether the line became grounded during the discharge.

Wm. McClellan: While deciding on the lightning protection for a sub-station which takes current at 60,000 volts and delivers it at 11,000 volts to a trolley line, we were impressed with the well-known fact that the selection of lightning protective apparatus depends on the amount of power back of the stroke and the voltage of the line to be protected. For the 11,000-volt circuit a form of multigap arrester was used. Perhaps some of these multigap arresters are better than others, but any well-designed one will answer for low voltages. The small amount of lightning that we have had this year has burned the gaps somewhat; this we know is the chief difficulty in connection with the multigap arrester. For the 60,000-volt lines, outdoor arresters of the horn type were used. There are three horns on each leg of the three-phase circuit. In series to ground with one of these horns is an enclosed indicating fuse 6 ft. long; this fuse works very definitely and positively, although it has not yet operated in connection with lightning discharges. A second horn has in series to ground a resistance made up of concrete blocks. The third horn has in series to ground one of the electrolytic arresters described by Mr. Jackson several months ago. It

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is hoped to show that the electrolytic arrester will take care of all discharges through the lightning season. If this proves to be true, increasing experience will warrant us in discarding all other types and depending solely on this type of arrester.

Such an arrester is in the nature of a safety-valve. As soon as the pressure rises to a certain critical point, it provides a free path of very low conductivity to ground; and when the accidental pressure on the line is relieved, the arrester comes back to its normal resistance. Such an arrester will be operated with a gap in series just large enough to prevent the normal voltage from breaking over. A horn in this case is entirely unnecessary, since the arc is opened by the small arrester current after the accidental high voltage is relieved.

I agree in general with everything that is said in the paper in regard to the horn arrester, but I do not believe in an arrester consisting of various horns with graded resistances. When extra turns are put on the transformers and powerful insulators on the line, all designed to take care of the certain rises in voltage, there seems little use in applying horn gaps with high resistances in order to relieve the line of rises in voltage slightly above normal. I think the horn arrester has been found useful only in those places where there is sufficient power back of it, so that the current passing over the horn is not large enough to shut down the station. In other words the horn type is successful in those few places where one can wait for the horn to open the circuit. It should be remembered, however, that under certain wind conditions, and also if the horn is not correctly shaped, it may be an excessively long time in opening the discharge circuit.

My faith in the electrolytic arrester has grown, so that for circuits of approximately 11,000 volts I would be inclined to use this arrester indoors; for circuits of approximately 60,000 volts I would use the electrolytic arrester also, with or without a horn, supported, however, as a last resort by a sturdy gap with enclosed fuse in series to ground. Such an enclosed fuse containing a No. 30 copper wire will open the discharge circuit in less than one cycle, whereas from 30 to 60 cycles is the usual time for the horn type under the best conditions. With either, on all circuits, choke-coils should be used beyond the arresters.

R. P. Jackson: Regarding the non-arcing quality of the so-called non-arcing metal: Mr. Rushmore, I believe, ascribed it to the boiling point of certain elements in the alloy. I think one thing has been lost sight of. Years ago, when Mr. Wurts first made the discovery of non-arcing metal, he found that there were certain metals belonging to one group that had that quality to a large degree, and other metals did not have that quality to any considerable degree or to any degree at all. These metals were cadmium, mercury, and zinc. They are all monatomic; that is, their gases are formed of molecules of one atom. This has a very important relation to the non-arcing

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quality, in that the gases have twice the volume that gases from other metals have. Also it is highly probable that a comparatively small number of ions will exist in the gases. Therefore, there would be much less chance for the arc to establish or maintain itself, and possibly a much greater local pressure when the spark occurs in the gap; that is, when the spark passes there will be between the surfaces of the metal a momentary great rise of pressure.

In regard to the "ideal" arrester, I think that it must be considered as a reasonable development from previous arresters used. The original non-arcing metal consisted of a single row of gaps. It was found several years ago that double the number of gaps, with half of them shunted, would form an arrester of the same equivalent as the original gaps. This can be extended, adding more resistances and more gaps, gaps being shunted by the resistance; but the equivalent begins to rise, and if another step is added, it rises somewhat more, and soon gets to a point where nothing is gained. There is not very much to be gained from more than the one step; but the equivalent will not rise quite so rapidly as the number of gaps themselves. The explanation seems to be that there is a time-period in the breakdown of the gaps; that is to say, they are not simultaneous, but consecutive.

Fuses are very good devices where they are properly arranged. In several places I have tried a fuse in parallel with the series resistance of an arrester. Such fuses will perhaps blow once or twice in a season; but when they do blow, they are badly needed.

Regarding the horn arrester, I am not sure that the rising of the arc is due to magnetic effect. Experimentally I have not found that true. I understand that at the Ontario Power Company's station the horns were arranged with coils to increase the magnetic effect, without much gain being found. I think the virtues of the horn arrester lie chiefly in its mechanical characteristics; it is comparatively simple and cheap. It has some non-arcing or arc-suppressing quality, but it has no such arc-suppressing quality as the multigap arrester. If something can be put in series with it that does not offer great impedance to the discharge of lightning or other energy, it may become useful.

The electrolytic arrester, so far as I have been able to learn, has just the characteristics that Mr. McClellan describes. It has a certain equivalent that is controlled largely by Ohm's law. If the area of the plates or the electrolyte is increased, the equivalent is decreased. If the length of the electrolyte is increased the equivalent is increased, and that equivalent seems to have comparatively little relation to the volume of discharge through it, so that it seems possible to predetermine the voltage which could escape through the arrester and simply short-circuit everything above that. In the type of electrolytic arrester which I have used, however, I do not consider it to be

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the counter electromotive force that limits the power current; there seems to be a dielectric film, and that film is capable of puncture and also capable of resealing when the voltage drops below a certain point. It acts like a valve with a spring behind it. When the film is punctured, if the excessive static voltage exists long enough, there will be a very large power current flowing through, but of course the high voltage due to lightning or surges exists for a very short interval, so the power that follows is insignificant.

C. P. Steinmetz: Omitting the fuse shunting the gaps requires that the gaps be always left in circuit, so that after the fuse blows there is still the same protection to the system as there would be when no fuse is used. The fuse gives a far better protection for most of the time and under most of the conditions than would be permissible without it. This use of a fuse, therefore, is not analogous to the fuse in series with the horn arrester.

Some of the questions raised refer merely to matters of terminology and would be very interesting discussions to fill the volumes of a purely scientific body. They are of comparatively little interest to an engineering society; for instance, whether the effect of some metal cylinders discovered by Mr. Wurts, and published in his classical paper fourteen years ago, might be called rectifying, or might be due to some mysterious action of some mysterious bodies, ions, jolting around in some manner—all this is quite immaterial to me. Mr. Wurts called the phenomenon " non-arcing ". Mr. Creighton finds two conditions: first, if the shunt resistance is low the disruptive discharge across the cylinder is not followed at all by the generator current; secondly, the disrupted discharge is followed by the generator current during one-half wave, but no further; that is, no reversal of the generator current can take place. Mr. Creighton adopted Mr. Wurts' term for the first condition; that is, called the case "non-arcing", where no generator current follows, and he gave the name "rectifying" to the case where the current can follow in one direction only, but cannot reverse.

Whether the non-arcing character of these metals is explained as being in one group—which, incidentally, is not quite right—does not seem to be a matter of very great importance. If I recollect aright, Mr. Wurts mentioned bismuth and antimony as non-arcing; these do not belong to the zinc group, though other metals which do belong in the zinc group are not generally recognized as non-arcing. The order of the non-arcing character of the metals as given by Mr. Wurts is the order of their boiling points. All this might be an interesting subject for a purely scientific or metaphysical paper, but does not seem to be of any particular value to us.

D. B. Rushmore (by letter): Many of the points brought out by the first speaker in the discussion are answered by a more careful reading of the paper or by the other speakers.

It is agreeable to find that the statements made concerning

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the horn arrester are in agreement with opinions held by men of such experience as Mr. Thomas and Mr. Converse.

It is stated somewhere in the paper that the illustrations showing the scheme for protection of wood pole lines are simply diagrammatic. Attention should, however, be called to the fact that the multigap arrester described in the paper is entirely new in design, and a careful reading of the action of the discharge over the multigaps will explain the difference in principle between these and former multigap arresters.

E. E. F. Creighton (by letter) : Some one has observed that the liquid electrode arrester is wet. That is true: it is the condition sought for. After having gone over a number of different methods of preventing or extinguishing an arc, I have come to the conclusion that with but one possible exception, not yet published, the liquid gives the most valuable property to the lightning-arrester.

The objection to the liquid, as suggested by Dr. Perrine, lies in the necessity of maintaining a certain level, and it might be added to keep the liquid from splashing. This is a simple engineering problem which seems to offer no difficulty in its solution. There are several solutions being tried out at the present time, any one of which seems to be practicable.

The loss of liquid through the operation of the arrester by lightning is too slight to take into account. For example, one of these arresters was put into operation three hundred times, which would easily cover a whole season's storms even in the worst locality, and at the end of the test the level of the liquid had not been lowered to any measurable extent. The energy given out by the electric current in the arc is absorbed, first in raising the liquid to boiling temperature; secondly, in the latent energy of changing the liquid to a gas; and thirdly, in the chemical energy of dissociation of the gas. To carry through this process requires a relatively great amount of energy for a small amount of electrolyte. The amount of electric energy given off from the generator is comparatively small because the current is limited by the voltage absorbed in the arc at the surface of the electrolyte. In case of continuous discharges over the lightning-arrester due to a grounded phase on an insulated Δ or Y system, the electrolyte is gradually used up until the arc distance is too great to be bridged by the surges on the line. This, as already stated in the paper, will require a number of minutes, and it will be necessary after such an operation to refill the jars with water to the original level. It should be noted that the arrester is not damaged by this continuous operation.

In considering the operation of the liquid electrode arrester, the brief and convenient term, "variable resistance" was used but it is important to distinguish carefully between the effect obtained from a counter electromotive force and the effect from a variable resistance. Although the counter electromotive

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force gives the same effect as an increase in resistance in reducing the current, yet it differs materially in that it reaches a limiting critical value above which it offers no further obstruction to the current flow. From zero up to the critical voltage the ohmic resistance of the cell has probably diminished although the effect of the arc is that of an increase of resistance.

Dr. Perrine's kind expression of appreciation of the work on this new cell type arrester reminds me that it was he that first recognized the value of the aluminum cell-type arrester and aided most in its development when I began working on it some six or seven years ago.

In regard to the leakage of current between cylinder and cylinder of the multigap arrester. The experience we had some years ago will corroborate Mr. Thomas's statement. Instead of using individual units of porcelain, Mr. Wurts decided to use one slab of marble with the cylinders arranged in zigzag form, but it was found that the spark voltage or equivalent-needle-gap of the same number of gaps as used previously with the porcelain units was very greatly increased. The leakage of current though the marble was sufficient to prevent the separation of the positive and negative charge on each cylinder, and the consequent resultant static induction to the next adjacent cylinder. The ten-pin or card-house effect was lost. The drop of potential across the marble was uniform, the high frequency between cylinders was lost, and many of the gaps were in a condition of partial short-circuit due to the concentration of the leakage current in the marble in the shortest distance between terminals. I still have in my laboratory an expensive board made up in this way which is entirely inoperative as a multigap arrester.

Mr. Thomas calls attention to the short-circuit current shown in one oscillogram as only 200 amperes. This I might state was under a particular condition where only one small machine was on the circuit, and the short-circuit current shown in some of the other oscillograms is more than double the value stated. By considering the condition of discharge of the new type multigap arrester it will be seen that the generator capacity is amply sufficient to give the effect that might be obtained from a machine of any capacity. When the spark takes place across the shunt gaps, the generator is producing full potential across the arrester and the voltage is not decreased by the discharge of the dynamic; consequently if the spark is going to form into an arc there is every reason for it to do so regardless of the generator capacity. Stated otherwise, if the potential of the generator does not decrease, the experimental conditions of test are correct and nothing further could be obtained by using a generator of greater kilowatt capacity. This statement is general and applies also to the tests of the liquid electrode arrester. I admit of course that if the spark does form into

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an arc the damage caused will increase directly with the capacity of the generator.

C. P. Steinmetz (by letter): It seems to me that the disagreement on the horn arrester is more apparent than real: it depends upon what is expected of an arrester. Mr. Rushmore defines a lightning-arrester as an apparatus capable of discharging any abnormal voltage or abnormal frequency without interfering with the normal flow of current. This the horn arrester does not do. With series resistance it is limited in discharge capacity; without series resistance it may protect the system; but it short-circuits it, so shuts it down temporarily.

Mr. Thomas' criticism of the definition of "lightning" seems justified. It is rather strange to speak of "lightning-arresters" in underground cable systems. I have not introduced this definition; but it has gradually introduced itself in practice, and so will probably stay. The proposed name "static", however, I do not approve at all. The term "static" has been used to a considerable extent, and mostly abused. Occasionally one hears of such anomalies as "static transformers," instead of "stationary transformers". If "static" means anything, it can only mean electric phenomena of such limited power as not sufficient to produce an appreciable current; that is, phenomena in which the electromagnetic component of the field is negligible compared with the elctrostatic component. A short-circuit surge which bends heavy copper bars can then hardly be called static, but the lightning-arrester should protect against it.

In my paper I have drawn analogies between electric waves, and waves in a body of water. It is obvious that such an analogy, though elucidating the phenomena, is not complete. For instance, in an electric circuit the tendency to form stationary waves or oscillations from travelling waves or impulses is very pronounced; but in a body of water this tendency exists to a very limited extent only, since in the latter case the wave length is usually only a very small part of the total wave travel. I believe that Mr. Thomas misunderstands my comparison of the breaking of a wave train at the station with the ocean surf. Where complete reflection occurs, as at the open end of a line, a standing wave is formed from the travelling wave of the same frequency. An ocean wave, rolling on to a sloping beach, is, however, not completely reflected; it is only partly reflected, while partly it rushes up on the beach. Now at the entrance to a station an electric wave train is partly reflected, partly enters, and "surf" is the result of the interference of the various reflected and transmitted wave trains. This results in the formation of local standing waves. The surf is therefore not a complete reflection, but a breaking up of the wave. In this way an ocean wave on a sloping beach, is comparable with an electric travelling wave at the entrance to a station.

As regards the damping effect of a grounded overhead wire,

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it appears to be obvious that a current induced in the ground wire by a wave train in a transmission line consumes energy, and thus reduces the energy of the wave train. The energy dissipated by this induced current in the effective resistance of the ground wire is taken from the energy of the wave train in the main wire, and causes the latter to decrease more rapidly. The imperfect inductive relation between transmission wires and ground wires applies only indirectly in considering this effect. Of the total magnetic flux produced by the wave train in the main wire, and surrounding the main wire, only a part interlinks with the ground wire as mutual inductive flux; probably most of it passes between the conductors as self-inductive flux. This self-induction does not consume energy, and therefore does not dampen; but mutual induction consumes energy and so causes the wave train to decrease more rapidly.

In a lightning-arrester it is of fundamental importance not merely to discharge abnormal voltages or frequencies, but to discharge them with the least possible disturbance. This means to discharge over the highest resistance, which does not yet appreciably back up the voltage by its *Ir* drop. Sometimes the volume of discharge is such as to permit no resistance whatever. The lightning-arrester must therefore have a path of no resistance to ground. A half-wave discharge without any resistance is quite a severe shock, and should be avoided. For this purpose a medium high resistance in shunt is used to take care of most of the discharges; of the discharges that are too heavy for this resistance, most are still deflected over the "low resistance" of the arrester, so as to limit the dead short-circuit discharges to a minimum. Very many discharges, however, are of such small power that a resistance very much higher than the "medium resistance" can take care of them; and it is therefore undesirable to cause a fairly large dynamic discharge over the medium resistance every time one of these very small discharges occurs. For this purpose the high resitance has been added.

Mr. J. P. Jackson explains that the non-arcing character of mercury, cadmium, and zinc is due to these metal vapors being monatomic. It is unfortunate that helium and argon are also monatomic, but are by no means non-arcing; on the contrary, they are known to have abnormally low disruptive strength; that is, they require only a low voltage to maintain a discharge.

Wm. McClellan (by letter): It has always been difficult to get a physical conception of the action of the film used on aluminum electrodes, either of the type proposed by Mr. Creighton or the one proposed by Mr. Jackson some time ago. No physical conception can be had until a great deal more is known about this phenomenon.

The writer has always conceived of the film as being electrically porous so that up to a definite pressure it held the current, but beyond this pressure the pores, so to speak, opened, allowing the

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discharge to pass through freely. This conception seems reasonable when one views the formation of the film and sees the gradual decrease in the number of spark discharges all over the face of it, until finally upon the complete formation these discharges cease at pressures below the critical point. This conception is suggested by the old physical experiment of the hollow gold sphere which will hold a liquid until the pressure is raised to a particular point when the liquid squirts out all over the surface.

The writer has never been able to find or hear of more than two objections to the electrolytic arresters with the large surface as proposed by Mr. Jackson. The first of these objections is the possibility of the arrester being exploded or burst by a heavy discharge, the same as a telegraph pole or tree is frequently rent. In such cases the explosion or shattering is due to the fact that the conducting path is very circuitous and narrow and that there is a great concentration of energy in this path. In the case of the large surface lightning-arrester proposed no such condition can exist, as at the time of a heavy discharge there is a uniform path of high conductivity.

The other objection is the possibility of freezing the electrolyte. This objection, of course, would hold only in the case of high-voltage insulations where it would be necessary to put the arrester outside the station. The writer thinks that in case of this trouble with a three-phase installation of these arresters, it would be a comparatively simple matter to put the three sets of arresters either in a pit below the frost line or in a cabinet above the surface, according to drainage conditions. This would act to shield the arresters from wind and shaking. It is well known that a liquid if kept absolutely still will not freeze when brought to a temperature far below its freezing point. It would probably be found that the temperature would never get sufficiently low to cause freezing solid. Experiments show that it is only when the electrolyte is frozen solid that it ceases to have its peculiar resistance characteristics.

P. H. Thomas (by letter): Mr. Creighton speaks of the "discovery of the true non-arcing conditions of shunted gaps" which he distinguishes from "the unstable condition of a shunted arc" that "has been known for a long time", by considering the latter as a phenomenon having to do with alternaing current whereas the former is really a shunted direct current operating for a part of a cycle. This distinction does not appear to me to be well founded. If we have a number of gaps shunted by a resistance, and pass a static discharge through these gaps while they are connected to a source of alternating potential, there will be of course current flow through the resistance and there will be a tendency for current to flow through the gaps following the static discharge. Whether a sensible current will appear in gaps depends, obviously, upon the voltage maintained across the gaps regardless of whether there may be resistance in shunt or not; whether the current continues in the shunted

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gaps or not depends also on this voltage and not directly upon presence, absence, or value of the shunt resistances. If the source of current is able to supply a smaller amount of current through the resistance than will maintain an arcing voltage upon the gaps, manifestly no current will follow the static discharge in the gaps. If, on the other hand, a sufficient current can be supplied by the source of electromotive force to maintain a sufficiently high voltage upon the gaps, current must inevitably follow the static spark therein. The shunt resisance has not a direct effect upon the arc in the gaps; it merely effects the potential of the terminals of the gap.

If now the static discharge occurs at one portion of an alternation, the voltage at that moment impressed upon the gaps will have one value; if at another part of an alternation, another value. There must be a portion of each alternation during which the generator voltage is so low as not to allow current to flow in the gaps following a discharge. On the other hand, if the current capacity of the source be sufficient there will be times within the alternation when the voltage impressed on the gaps will be sufficient to cause a following of current in the gaps. The most favorable condition for such following is obviously that the static shall occur approximately at the maximum of the waves. It appears from Figs. 3 and 4 of Mr. Creighton's paper that the static discharge which he times with a synchronous motor occurs early in the cycle, at an instance when the generator electromotive force is far from its maximum. This condition is manifestly an unfavorable one for the following of current in the gaps. If Mr. Creighton has always passed the static through the shunted gaps at this part of the cycle, it would not be safe to draw any inferences as to the non-arcing quality of the arrangement under the conditions of actual service where the discharge is sometimes likely to come at the maximum of the wave.

The arc suppressing power of the shunt resistance depends entirely upon the current that is to pass through this resistance following the static discharge. The shunted lightning-arresters heretofore used have exactly the same electrical arrangement as Mr. Creighton's. When the current tending to flow in the resistance after a discharge is small, or when the discharge occurs at a low-voltage point of the cycle, no current whatever will appear in the shunted gaps. When, however, more current flows through the resistance there will be some current flow in the gaps this current will cease at the first alternation if it be not too heavy, or so much current may be forced into the gaps that they will continue the arc. There is no difference between the apparatus of Mr. Creighton and the previously shunted gaps; he has simply subjected them to milder conditions.

I would call attention to the curious form of the current curves in Fig. 1, which I believe to be generally correct. The first time it is met with, the high voltage at low currents is quite a surprising feature.

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HIGH-VOLTAGE DIRECT-CURRENT AND ALTERNATING-CURRENT SYSTEMS FOR INTERURBAN RAILWAYS.

BY W. J. DAVIS, JR.

The magnitude and direction of engineering development in apparatus for the electrical equipment of high-speed interurban railways is well illustrated by a study of the systems adopted by some of the more important lines recently built or now under construction. These systems may be divided into three classes, namely:

1. 600-volt, direct-current using either overhead trolley or third-rail.
2. 1200-volt, direct-current overhead trolley.
3. Single-phase, alternating current, 3300- or 6600-volt overhead trolley.

As apparatus for the operation of the 1200-volt, direct-current system is being manufactured in this country only by one company, the list of roads given below comprises only those using equipments manufactured by this company, and is limited to sales to new roads made during the last year.

The largest installation undertaken during the last year was that of the West Jersey & Seashore Railroad, comprising equipment for 145 miles of single track and 35600 h.p. in railway motors. On account of the limited time required for the completion of this installation (six months from date of selecting power-house site) it was impossible to furnish apparatus of special type, making the selection of the 600-volt, direct-current system obligatory. For this reason the equipment of this road is not included in the following statistics.

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	Length of track	No. of Cars	Size Motors	Total motor h.p.
600 volts, direct current				
Texas Traction Co.	63 miles	15	4 75 h.p.	4,500
Elmira, Corning & Waverly	15 "	7	4 60 "	1,680
Buffalo, Lockport & Rochester	70 "	19	4 75 "	5,700
Oregon Railway	40 "	8	4 75 "	2,400
	188 "	49		14,280
1200 volts, direct current				
Central California Trac. Co.	16 miles	6	4 75 h.p.	1,800
Pittsburg, Harmony, New Castle & Butler	63 "	12	4 75 "	3,600
Indianapolis & Louisville	41 "	10	4 75 "	3,000
Indianapolis, Columbus & Southern		3	4 75 "	900
San Jose & Santa Clara	9 "	8	4 75 "	2,400
	129	39		11,700
Single-phase, 3300 or 6600 volts			4 125	
Washington, Baltimore & Annapolis	52 miles	25	2 125	11,500
Central Illinois Constr. Co.	40 "	10	4 75	3,000
Anderson (S .C.) Railway	35 "	3	4 75	900
Richmond & Chesapeake Bay	15 "	4	4 125	2,000
	142	42		17,400

Total horse power in motors sold, 43,380 of which
600 volt, direct current has 33 per cent.
1200 " " " " 27 " "
Single phase alternating current has 40 per cent.

It is most interesting to note that two-thirds of the total motor capacity sold consists of 1200-volt, direct-current and single-phase alternating-current motors, indicating the eagerness of electric railway builders to take advantage of the reduced cost of construction and equipment, and economies in operation, resulting from the use of higher secondary distributing voltages. The magnitude of the possible savings will depend upon the local and service conditions and will vary over a wide range.

Generally speaking, increased voltage at the trolley will be attended with reduction in cost of copper and sub-station apparatus, and by increased cost of car equipments due to the inherently heavier and more expensive character of the motors and control systems. Where the car movement is especially frequent, as in case of rapid-transit suburban service in the vicinity of the larger cities, requiring from two to four tracks, the 600-volt, direct-current systems will generally prove the cheaper, a result largely due to the lower cost of the motors.

On account of the variable character of the conditions encountered, each problem requires a special investigation before the

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relative merits of the three systems can be reliably determined, but the following general limitations will be found to hold true.

1. Street railways and elevated roads in cities should unquestionably be equipped with standard 600-volt, direct-current apparatus.

2. Suburban lines 10 to 15 miles in length operating cars on frequent headway should be equipped with 600-volt, direct-current system.

3. For high-speed interurban railways operating cars 50 ft. or more over all at speeds of 40 miles per hour or more:

a. The 600-volt, direct-current system is the most reliable on account of being most fully developed.

b. The 1200-volt, direct-current system is somewhat cheaper in cost than the 600-volt system, but is as yet an untried system.

c. The single-phase, alternating-current system will in most cases show material saving in cost over the direct-current systems, and has been developed to a point where it may be considered commercially successful and capable of giving satisfaction in operation, if properly proportioned for the service to be performed.

There are certain conditions which render the alternating-current motor system unduly expensive or impracticable; namely, the enforced use of a frequency greater than 30 cycles, the presence of grades greater than 8 per cent., or the necessity of obtaining perfectly balanced three-phase load under all conditions. In such cases, the 1200-volt or the 600-volt direct-current system will prove the most economical, preference being given to the latter although the cost of installation will be greater.

The single-phase, alternating-current and 1200-volt, direct-current equipments may both be made to operate satisfactorily on standard 600-volt, direct-current systems, and assuming equal reliability, the question becomes one of first cost and economy in operation. The following table will show approximately the relative cost of a typical suburban road with the several systems.

It is of interest to compare the operating economy of the three systems, eliminating those items which are of equal value in each. The comparison given below is based on coal at \$3.00 per ton; coal consumption 3.5 lb. per kilowatt-hour; sub-station attendance \$1750 per annum; maintenance of car equipments, 0.4c. per car-mile for 600-volt direct current, 0.5c. for 1200-

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volt direct current, and 0.6c. for alternating current, and fixed charges at 10.5%.

COMPARATIVE COST PER MILE, SINGLE TRACK.

	Direct current 600 volts	Direct current 1200 volts	Alternating current 6600 volts
Roadbed complete including grading, ballasting, etc....	$15,000	$15,000	$15,000
Trolley and feeder installed	3,800	3,000	2,100
Track bonding	600	530	480
Transmission line, installed	1,500	1,500	1,300
Sub-stations, installed	2,200	1,600	600
Power station, installed	2,450	2,450	2,570
Cars and equipment	1,800	1,970	2,300
Telephone	120	120	120
Total	$27,470	$26,170	$24,470
Saving over 600 volts, direct current		1,300	3,000

RELATIVE OPERATING COST PER MILE SINGLE TRACK PER ANNUM.

Per mile of track, one-hour headway	Direct current 600 volts	Direct current 1200 volts	Alternating current 6600 volts
Car-miles per day	64	64	64
Kilowatt-hours per day at power house	275	275	245
Cost of coal per annum	470	470	419
Cost of sub-station attendance	175	79	46
Maintenance of motors and control	94	117	140
Total	$739	$366	$605
Saving over 600-volt direct current exclusive of fixed charges		73	134
Saving in fixed charges		137	315
Total annual saving		$210	$449

Another method of comparison is to capitalize the annual saving exclusive of fixed charges. Assuming fifteen years as the average life of equipment and construction work, the present value of the annual saving in operating expenses per mile of track at 5% interest will be:

For the 1200-volt, direct-current system	$ 756
To which add saving in first cost	1300
Making the total capital value of	$2056 = 7.5%
And for the 6600-volt, single-phase system	1390
To which add saving in first cost	3000
Making total capital value of	$4390 = 16%.

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The above comparison is based on service and construction conditions applying to the typical high-speed interurban electric railway, the fundamental assumptions and principal data being as follows;

Length of road, 50 miles or more.

Cars 52 ft. over all, weighing 21 tons without equipment or load and seating 56 passengers.

Car equipment, four 75-h.p. motors.

Maximum speed on tangent level track, 45 miles per hr.

Schedule speed 24 miles per hr. including stops and slow running through towns.

Headway, maximum service, 0.5 hour.

Frequency of stops, one in two miles, interurban.

Average car energy, 85 watt-hours per ton-mile at car.

	Direct current 600 volts	Direct current 1200 volts	Alternating current 6600 volts
Cost of cars equipped	$10,800	$11,800	$13,800
Spacing of sub-stations	10 miles	22 miles	32 miles
Maximum voltage drop, trolley line	25%	25%	10%
Efficiency of system, generator bus-bars to cars	71%	71%	84%
Average efficiency car equipment	75%	75%	73%
Average power-factor of system	96%	96%	85%

As the 1200-volt, direct-current system is still in process of development, a brief description may prove of interest.

The roads which are now being equipped may be divided into three classes: 1. Those which are required to operate on 600-volt direct current at full maximum speed as on the 1200-volt sections; 2. Those which are required to operate on 600-volt direct current but at approximately half maximum speed; and 3, those which operate only on 1200-volt trolley.

The first class requires motors wound for 600-volts but designed to stand 1200 volts without danger of flashing or injury to the insulation. The motors are connected four in multiple when run on 600 volts and in two parallel groups of two motors in series when run on the 1200-volt sections.

In the second and third classes the motors may be wound for either 600 or 1200 volts, preference being given to the latter on account of improvement in tractive power at the slipping point of the wheels. In order to obtain satisfactory commutation qualities and to control the tendency to flash at the commutator at the high voltages encountered, all motors for the 1200-volt

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system are provided with a compensating winding in the shape of series wound auxiliary poles located midway between the magnetizing poles and so proportioned as to neutralize the armature reaction under all loads. The additional insulation required causes the motors to weigh 15% to 20% more for a given output than 600-volt motors. This additional weight is not due to the inter-pole construction, as on the basis of equal voltages the inter-pole motor will weigh about the same or a little less than the standard railway motor.

The control system is substantially the same as that used on the 600-volt system, with the exception of some slight changes in the insulation of the primary circuits. The secondary circuits are all energized at 600 volts, as are also the car heaters and lights, and for this purpose a small dynamotor is furnished for use when run on 1200 volts, the function being to change the voltage to 600. The capacity of this dynamotor as furnished with quadruple 75-h.p. equipment is 38 amperes, which provides for the lighting, heating, and air-pump circuits for one car, and secondary control circuit for a train of six cars.

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Discussion on "High-Voltage Direct-Current and Alternating-current Systems for Interurban Railways," at the Chicago Branch, March 26, 1907.

James Lyman: No branch of engineering is more active than that engaged in the electrification of transportation systems, so Mr. Davis' paper is as timely as it is interesting and instructive. The network of interurban railways in the middle West is one result of this activity. There is one system of electric railways centering in Indianapolis having 400 or 500 miles of road, and another in the central part of Illinois having about 300 miles of road, with 150 miles more now under construction.

Mr. Hesing: It has been pretty well demonstrated what the 600-volt, direct-current motor will do, but possibly it is not quite so well understood what the alternating-current motor will do. Just at present I have charge of a little alternating-current line, and maybe a short description of what we do will be of some interest. We operate at 3300 volts. The line is about 22 miles long, with no sub-stations whatever. We have a 00 trolley wire. In fact, we started out with two 00 trolley wires, and one was moved over to the pole and now acts as a feeder. The cars are not very large, about 35 tons, requiring 75-h.p. motors. To my mind, the operation has been very satisfactory. Our records show that the cars have run from 75,000 to 85,000 miles with only one furbishing of the commutators, and they run from 5,000 to 6,000 miles with one set of carbon brushes. We subject our cars to pretty severe treatment. They are geared for 42 miles an hour, and as the road is quite small and sometimes pushed beyond its capacity, a couple of ordinary flat cars are used for trailers, side boards are put around them and folding-chairs are provided. These are called "chair cars", and probably 600 or 800 people are hauled at a load. It doesn't look very nice, but it pays.

I am glad that the speaker says the alternating-current system is of so much value. I can hardly see how it can be improved upon, except in one particular—the acceleration of the motors is slow. Our stops are not frequent, but where, as in the city practice, stops are very frequent, I think the service would be a little bit slow. Paralleling the Alton, when we made a run for that, we had no trouble whatever to give the same service as the expensive red train. So I think that for a little road—really an experimental road—the alternating-current system is the thing to use.

Mr. Gould: Having had experience only with the standard 600-volt, direct-current system, I am more in the nature of a questioner. I would like to ask Mr. Davis as to the relative costs of maintenance of the line and trolley system of the two; that is, how much does the line maintenance of the alternating-current system exceed that of the 600-volt, direct current-system?

W. J. Davis, Jr.: The single-phase system has not been in

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operation sufficiently long to permit complete standardization of the line material. Such experience as we have had, however, indicates that a 6600-volt overhead trolley system using catenary construction may be made very reliable and durable, and should give a maintenance cost at least equal to the best 600-volt, direct-current construction.

Peter Junkersfeld: In making comparisons on the cost, I notice that Mr. Davis has used a figure of 10.5% fixed charges and he has applied that to all three systems. It seems to me from what I have heard and from what Mr. Davis has told us, that if 10.5% is fair for the 600-volt system it is liable to be somewhat low for the other two systems, for the reason that they are somewhat new and untried. It seems quite low to me even for the 600-volt system.

W. J. Davis, Jr.: That 10.5% does not represent maintenance. It simply represents interest, taxes, insurance, depreciation, and charges of that nature, with interest at 5%. These are independent of the kind of system used. The depreciation has been taken the same for each system; that is, life of buildings 40 years, copper and line equipment 20 years, rolling stock 15 years. These values are rather low than otherwise for a good system. It is possible to get more than 15 years out of modern car equipments, if well maintained.

Peter Junkersfeld: What I have in mind is, on the new and untried systems there would be quite a considerable "antiquation charge"; that is, the system will probably be perfected a great deal more in the next five or ten years, and part of the equipment will probably then be obsolete.

W. J. Davis, Jr.: That is true. Taking that into consideration the fixed charges should be somewhat higher.

Peter Junkersfeld: And that in time would make it a little more favorable to the 600-volt system. Another question: how does the maximum allowable drop compare in the two systems?

W. J. Davis, Jr.: The maximum momentary drop permissible in the 600-volt system should not, as a rule, exceed 50%; most systems are usually calculated for about 25%. The latter condition will give about 5% average energy drop, depending upon the frequency of the service, grades, and other conditions. In the 6600-volt, single-phase system the average allowable drop in the secondary distributing system is usually fixed at 5%, including that in the rail return, with swings approaching 10%. It must be remembered that in the alternating-current system the drop in the various sections between the car and the power station bus-bars is cumulative. In addition to the drop in the trolley line and track, there is an energy drop and reactive drop in the step-down transformers, transmission line, and step-up transformers. Finally, there is the regulation of the generators and the drop in speed of the engines when the car starts. These are all cumulative in their effect. In a direct-current system,

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on the other hand, we have only to consider the drop from the sub-station bus-bars to the car. For the above reasons it is necessary and desirable to allow a much smaller maximum drop in an alternating-current system than in a direct-current trolley system. A maximum voltage drop of 10% in trolley and track of a single-phase system will often correspond to 25 or 30% drop in the whole system.

W. A. Blanck: Mr. Davis makes a statement about 40% of these roads being single-phase roads. I must say I have enjoyed the statement very much, because we have tried in the middle West to find railways on which we could use the single-phase system. Most of those we have investigated found it almost prohibitive to use the single-phase system, because of exchanging rolling stock with other roads and running into the cities where direct current is used. Furthermore, we find it very difficult always to use high potential in the cities themselves. Is it possible to overcome these difficulties? Most of our systems run into cities where we can not use the alternating-current system to-day.

Mr. Davis proposes to put the sub-stations about 32 miles apart, which would give 16 miles on each side for one section. That is rather long and it makes the section dependent on any kind of breakdown in that long section, so that more subdivisions with feeders or more frequent sub-stations will be required. Have these questions been investigated, and has any difficulty been found in placing the sub-stations so far apart?

W. J. Davis, Jr.: I do not think it necessary to place sub-stations closer together, because of possible unreliability in the secondary distributing system. It might be well to have a switch on a pole suitably located so that a part of the line may be cut out for repairs. If the line is properly erected, a 30-mile section, where cars are operating normally on one-hour headway with a maximum of one half-hour headway, ought not to be considered excessive in the light of past experience. The time may come in the development of the alternating-current system when sub-stations will be omitted entirely and 11,000 volts will be fed direct into the trolley with power stations located 30 to 50 miles apart. If the load-factor is sufficiently good to warrant the use of this arrangement, the system is reduced to the basis of the ordinary city railway system so far as simplicity and reliability are concerned. Some of the 6600-volt, single-phase roads now being installed will feed out 15 or 16 miles from one sub-station.

W. A. Blanck: It is necessary to enter cities with interurban roads. If steam-road conditions prevailed, if there were isolated terminals, an alternating-current system would be practicable, but interurban roads generally terminate in a city, and must operate therein by the direct-current system. We are all convinced that the alternating-current system is a coming system much less investment for same amount of traffic done--but

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present operating conditions almost make it prohibitive to put it in.

W. J. Davis, Jr.: So far as the motor is concerned, the alternating-current motor can be built to operate as well on direct current as the ordinary direct currrent motor. Several instances have come under my observation where a combination of the 600-volt, direct-current and 6,600-volt single-phase sytems has made it possible to secure an increased economy in operation and also a considerable saving in cost.

I have in mind the case of a road 65 to 70 miles long. On the first 15 miles the service will be extremely heavy, requiring the operation of two- or three-car trains on 15-minute headway with frequent stops. The rest of the road will require the service of single cars every hour. There will be required a rolling stock equipment of about 30 cars, of which 25 will operate on the 15-mile suburban section and the remaining five on the longer interurban section. A straight single-phase system will prove objectionable on account of the intrinsically higher cost of the car equipments, due to the frequent service; on the other hand, the straight direct-current system will prove expensive on account of the larger number of synchronous converter sub-stations required on the 40-mile interurban section. A combination of these two systems, the 15-mile suburban system being equipped for direct current and the 40 miles interurban section for alternating current, will prove cheaper in first cost and more economical to operate than either system considered separately. This combined system will require two alternating-current sub-stations on the 40-mile interurban section, two direct-current sub-stations on the 15-mile suburban section, twenty-five direct-current equipments, and five single-phase equipments. The objection from an operating standpoint of having two types of motors is more than counterbalanced by the possibility of securing the most desirable operating features of both systems with the objectionable features of each reduced to a minimum.

T. F. Clohesey: What is the relative efficiency of these motors while running? For instance, a 300-h.p. car at full load alternating current and then when it enters a city and has to operate on direct current? What is the efficiency of the same car provided there are no stops?

W. J. Davis, Jr.: It will be about 2% better on direct current than on alternating current.

W. A. Blanck: Have you overcome all the difficulties now in regard to interference with telephone lines? I have heard that in the East especially there are frequent complaints from telephone subscribers in the interurban districts—they have complained of interference with the service.

W. J. Davis, Jr.: There were complaints in the early days, because we had no operating experience with the actual conditions existing between the telephone lines and the single-

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phase lines, but within the last year we have found out how to cure all of the troubles. I do not know of a single case where, if proper consideration is given to the system when it is first put in, there should be any trouble with the telephones.

W. A. Blanck: There is another very interesting question to be settled—the bow versus the trolley. In the different tests mentioned, which arrangement has been used for collecting the current from the conductor?

W. J. Davis, Jr.: That question is probably the most vital of the whole alternating-current system. No overhead collecting device has yet been devised which experience has shown to be safe and reliable and to have a low maintenance at a speed exceeding 60 miles an hour. The third-rail is the only system which has been proved to be absolutely satisfactory. There have been several bow collectors designed, but none of these has been operated long enough to show exactly what maintenance could be expected from it. After a little more experience we may probably produce some form of collector which will have a longer life than the present form.

W. A. Blanck: What difficulty have you experienced in regard to the suspension of the trolley wire in the catenary form. Where the suspension points are less than three feet apart, do you find in running 60 miles an hour that each point gives a particular shock or kick to the bow, or do you overcome these difficulties? Have you been able so far to see what it will take to keep up the catenary construction work? Have you any data on these matters?

W. J. Davis, Jr.: No; we haven't any data to cover any period of time of sufficient length to be reliable. The suspension points in my opinion ought to be 15 to 18 ft. apart; this spacing giving the best results at high speeds where bow collectors are used. Where a wheel collector is used, the spacing between suspensions may be made 50 ft, or about three to the interval between poles.

W. A. Blanck: Have you found it necessary in your exerience to bond both tracks for single-phase service? or do you think it is sufficient to have only one track rail bonded, and in case of double track to have one cross-bond every half mile or so, or do you find it necessary to put a bond on each track?

W. J. Davis, Jr.: It is usual to bond both tracks, because of greater safety, but I do not think there would be any great danger if only one track were bonded. In many high-tension systems a ground wire is carried on the poles as a lightning protection. If that ground wire were connected to the rail at suitable intervals trouble would be prevented.

W. A. Blanck: My special question with reference to that is whether one of the rails can not be used for signal service, and if it is what interference is there from having only one rail bonded and alternating current in one rail, while perhaps there is another frequency for single phase in the second rail, which I understand to a certain degree is used in the New York Central.

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W. J. Davis, Jr.: I do not know of any case where that arrangement is used, but I can think of no objections to it. It would appear to be perfectly safe if a ground wire is run in connection with the track return.

L. M. Zapp: Mr. Davis, in his statement as to direct-current efficiency, said I think 71 per cent. from power station to the car on 600 volts. Is not that rather high?

W. J. Davis, Jr.: The value given is based on 90% efficiency for the trolley system, 83% for sub-stations, including transformers and synchronous converters, and 95% for the transmission line.

L. M. Zapp: Of course that would depend on the load-factor and also on the magnitude of the system, whether it is only a 50-mile system operating from one power station, or a 300-mile system. The load-factor on an interurban line operating half-hour or even hour schedules will very seldom be greater than 35%, if storage-batteries are not used. May I ask Mr. Gould if he remembers just what his figures are?

Mr. Gould: They will not average 35%.

W. J. Davis, Jr.: Do you remember what your efficiency is?

Mr. Gould: About 75% from the sub-stations bus-bar.

L. M. Zapp: In a paper written by Mr. A. S. Richey, electrical engineer of the Indiana Union Traction Company, he said that the average efficiency of transmission from power station to the car motors on that system was a little better than 56%. That was on about a 300-mile, single-track system. I was connected with that road, and I remember that with 13 sub-stations we got an average efficiency from power station bus-bars to sub-station bus-bars of about 70%. The sub-stations would average about 15 miles apart. The feeder was nearly all 500,000 circular mils. Mr. Richey's later tests showed that the average efficiency to the car motor was only about 55 or 56%. That being the case, it would make the figures still more favorable to the alternating-current railway.

I. E. Brooke: In the alternating-current system with sub-stations 32 miles apart, what system of lightning protection is used for the catenary? Is there any other protection than that at the sub-stations themselves?

W. J. Davis, Jr: I think it would be well to have lightning-arresters more frequently than at the sub-stations. It is usual to place pole arresters about one mile apart.

I. E. Brook: It is a simple matter in a direct-current system to put up a lightning-arrester on a pole every 1000 ft. or so. With 6000 volts it is a different proposition.

W. J. Davis, Jr.: Yes; they should be boxed in.

I. E. Brook: What are railway engineers doing at present with three-phase motors for heavy power work? Has that proposition been dropped or are they still considering it?

W. J. Davis, Jr.: There is quite a well defined field for the three-phase motor. That field, however, apparently does not

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exist in interurban railway work, but it has been found to be especially applicable to hauling trains on heavy mountain grades reaching 2% and 2.5% and covering sections of 10 to 30 miles. By the use of the three-phase motor, it is possible without material complication in the control system to return power to the line on descending grades. Power saved by such regeneration is of secondary importance, however, as the greatest gain is made by the saving in wear on wheels and brake-sho s.

The company with which I am connected has not yet built a locomotive of this type, but a large number of designs have been investigated, and there are no physical reasons why such locomotives cannot be built as powerful and as reliable as direct-current or single-phase locomotives.

H. R. King: What is the character of the station in a 1200-volt-direct-current equipment; that is, the character of the generator equipment?

W. J. Davis, Jr.: With one exception the roads now being built will use two synchronous converters connected in series. It is perfectly feasible to build reliable 1200-volt, direct-current generators or synchronous converters. .

Mr. Hatch: In regard to the 1200-volt line now building from Seymour to Sellersburg. If I remember aright the current out of Indianapolis is 550 volts; then there is a stretch using 1200 volts, and on the other end of the line I believe it is 650 volts. Will they be able to run any car clear through on that line?

W. J. Davis, Jr.: Yes; the motors will be wound for 600 volts, and on the 550- and 650-volt sections they will run at full maximum speed with motors in multiple. For 1200 volts, the motors will be connected in groups, two series, two multiple.

Mr. Hatch: Would there have to be very much change in an ordinary direct-current car to do that?

W. J. Davis, Jr.: No; simply having a commutating switch which will change the grouping of the motors as the car passes from one section to the other.

Mr. Hatch: Practically the same speed?

W. J. Davis, Jr.: Yes. The volts per motor will be the same for 1200- as for 600-volt operation. There may be cases where it is desirable to run at half speed on the 600-volt section; namely, within city limits. Here it might be well to use a 1200-volt motor, although the same result can be obtained by connecting in series-multiple groups, using 600-volt motors.

E. N. Lake: What rate of acceleration have they been able to attain with the later single-phase equipments?

W. J. Davis, Jr.: That depends on the size of the motor and gear-reduction. Most interurban single-phase cars, geared for 40 to 45 miles an hour with four 75-h.p. motors, 42-ton car, will give about one mile per hour per second rate of acceleration. As a matter of fact, it is not essential to have a very high rate of acceleration for interurban work, because the

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stops are infrequent (averaging about one in two miles) and the difference between one mile per hour per second and a mile and a quarter per hour per second, would not materially affect the running time.

James Lyman: Mr. Junkersfeld has referred to the depreciation percentage. Mr. Davis' figures are, I think conservative. In the development of a new line of apparatus, like this alternating-current-direct-current car equipment, it is understood that there are some features that undoubtedly will become obsolete after a time and will have to be replaced. There is also a good deal of apparatus that can be depended upon as reliable and as slow in depreciation and good for many years. The question that confronts the railroad engineer is whether it is not better on new work where the conditions are favorable to get in line at the start for the alternating-current type of apparatus that will soon become standard practice and which will eventually, if not at once, show marked economy over the standard 600-volt, direct-current system.

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THE TRANSMISSION PLANT OF THE NIAGARA, LOCKPORT AND ONTARIO POWER COMPANY

BY RALPH D. MERSHON

On the seventh day of July, 1906, there was put into operation the first of the transmission lines of the Niagara, Lockport and Ontario Power Company. This event marks the inauguration of one of the first undertakings in the matter of distributing Niagara power over a large section of country, and the beginning of an enterprise which is one of the most important, and in some respects the most important, of its kind anywhere in the world.

The plans realized at present and contemplated for the immediate future, in the plant of the Niagara, Lockport and Ontario Power Company, involve a maximum transmission distance of 160 miles. This distance puts the plant amongst the longest transmissions of the world. As regards capacity, the plant of the Niagara, Lockport and Ontario Power Company is now one of the most important in existence, and, in the near future, its capacity will be far in excess of any other transmission system in the world. In addition to these points of importance, there are a number of engineering features somewhat out of the usual line of transmission practice which make the installation of interest from an engineering standpoint. Inasmuch as the description of such a plant is usually more satisfactorily accomplished through pictures than otherwise, they will be mainly resorted to herein, with the aid of only such brief text as may be necessary to cover points which cannot be well shown in illustrations.

The prospective system of the Niagara, Lockport and Ontario Power Company is a comprehensive one for the delivery of power

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in the United States within an economic transmission radius of Niagara Falls, and especially for its delivery in the northern and western portions of the state of New York. The company expects within the next two years to be transmitting 60,000 horse power, and its present right-of-way purchases are with reference to an ultimate transmission of 180,000 horse power. The plans of the company as at present laid out contemplate the transmission of this power by means of main lines and branch lines therefrom; the contracts for power being, wherever possible, made for delivery of the power at the main-line voltage of 60,000, less line drop. Where, however, the business of a given territory will justify it, the company will install step-down transformer stations for the delivery of power at a lower voltage. Each of the main transmission circuits will be capable of receiving and transmitting 30,000 horse power at 60,000 volts, and it is intended always to provide a sufficient number of spare main transmission lines to insure continuity of service on the main line. Spare lines will be provided in the case of branch lines only when the latter are of considerable importance.

The Niagara, Lockport and Ontario Power Company is only a transmission company; that is, it buys the power to be transmitted and has, therefore, no generating plant of its own. The power for the transmission is generated in the hydraulic power station of the Ontario Power Company, situated on the Canadian side of Niagara Falls. The water for this station is taken from the Niagara River, some distance above the falls, whence it is brought to a point at the top of the cliff, a short distance below the falls, through underground steel conduits, and from this point delivered through underground penstocks to the power station located at the bottom of the cliff, near the foot of the falls.

The power house contains the generating units with their exciters and switchboard apparatus. The generators have a capacity of 7,500 kw. each, and deliver three-phase, 25-cycle current at 12,000 volts. From the power station the current is taken at 12,000 volts to the transforming and switching station of the Ontario Power Company located on the bluff above the falls. It is stepped up from 12,000 volts to 62,500 volts, and at this latter voltage delivered to the transmission lines. The transmission lines of the Ontario Power Company extend from their transforming station to a point some six miles farther down the Niagara River, at which point the

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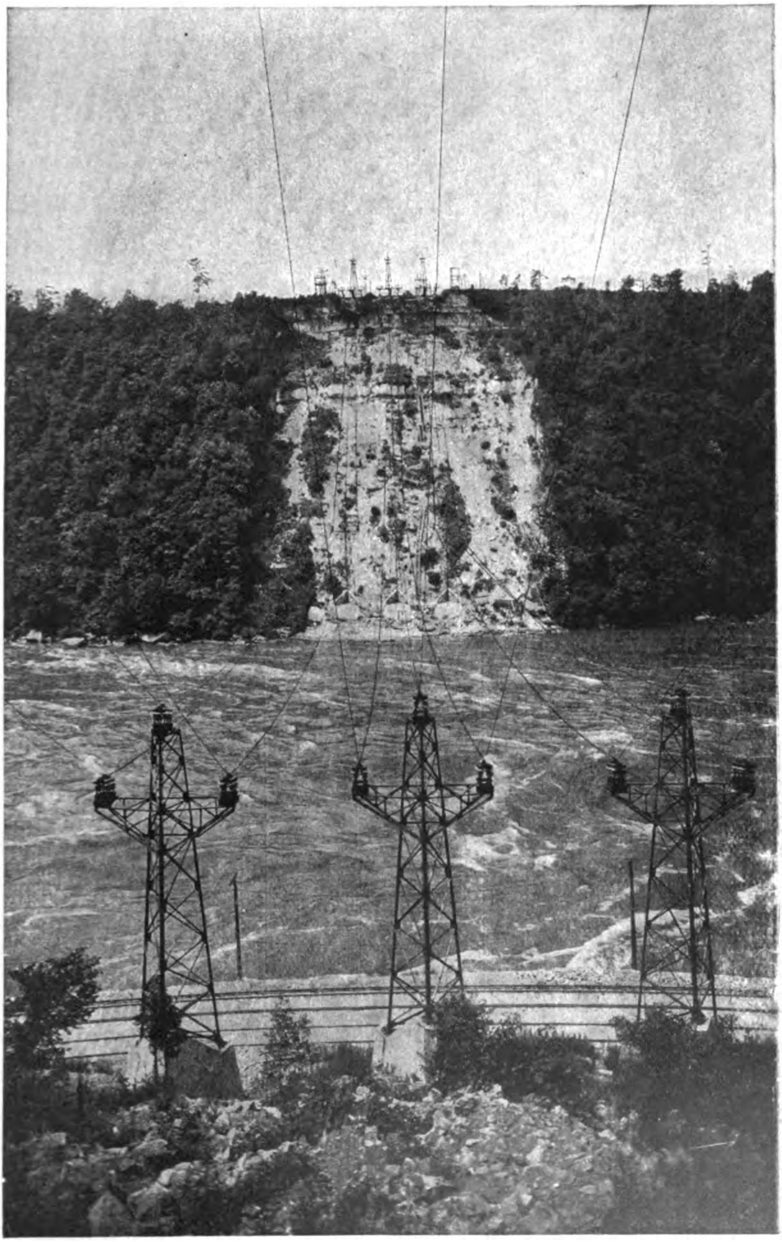

FIG. 1.—Niagara crossing, general view

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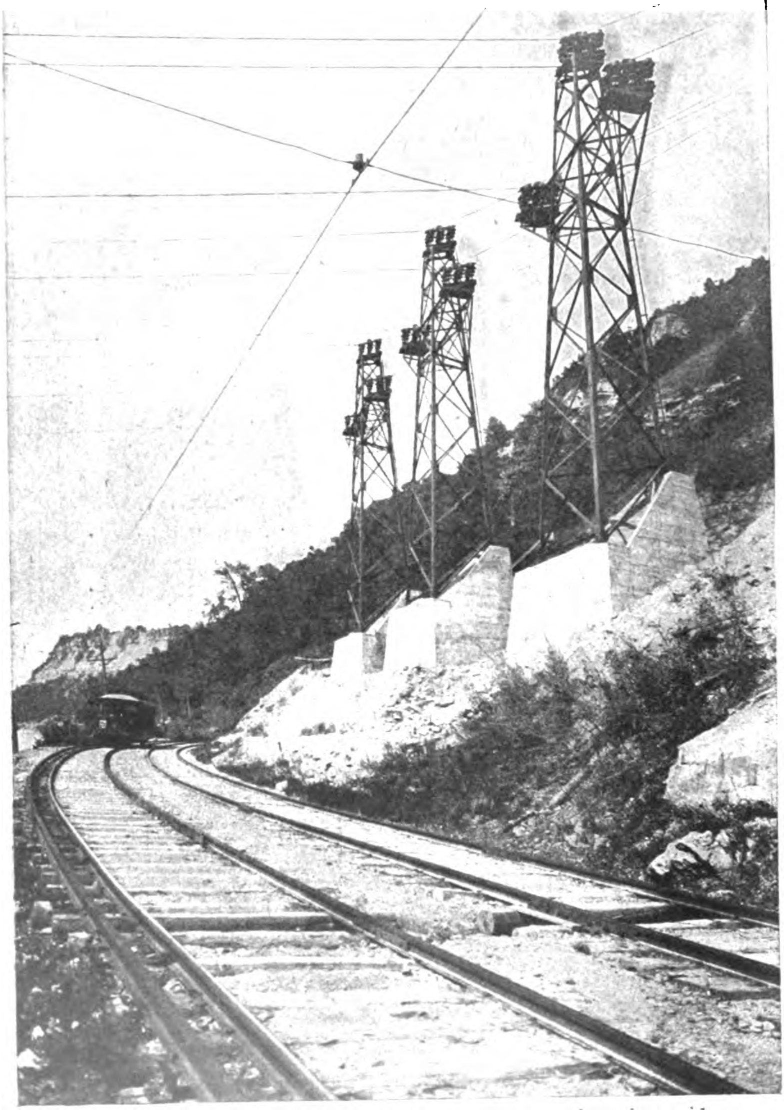

FIG 2.—Niagara crossing, water-edge towers American side

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lines connect to circuits spanning the Niagara River. The Niagara, Lockport and Ontario Power Company takes delivery of the electric power at the international boundary line in the middle of the Niagara River.

At the present time, the Niagara, Lockport and Ontario Power Company has in its possession a private right-of-way 300 feet wide from the Niagara River to the town of Lockport,

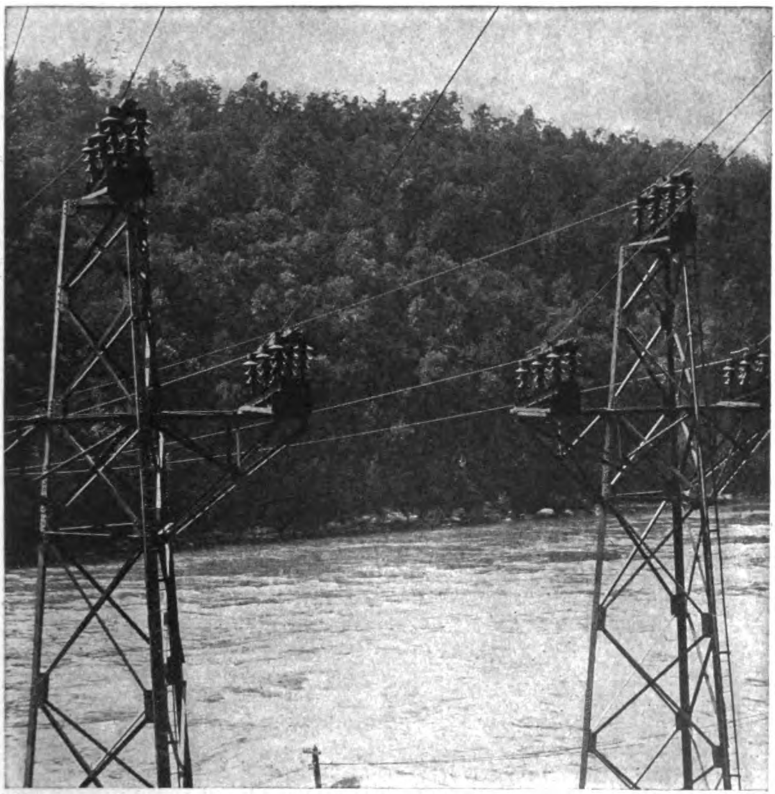

FIG. 3.—Niagara crossing, top of water-edge towers.

about 16 miles east; from Lockport east to Mortimer (six miles south of Rochester), a private right-of-way 200 feet wide, a distance of about 57 miles; from Mortimer to Fairport a 100-foot private right-of-way a distance of 10 miles; from Fairport to Syracuse a private right-of-way 75 feet wide, a distance of 71 miles. From Lockport south, in the direction of Buffalo, the company has a private right-of-way 100 feet wide. In ad-

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dition to this, the company has the right to install transmission lines on the right-of-way of the West Shore Railroad and has acquired the necessary private right-of-way to get from their main private right-of-way to that of the railroad company.

The installation which the company has now in operation is for receiving 30,000 horse power and delivering this amount, less the line loss. The main transmission consists of two lines in

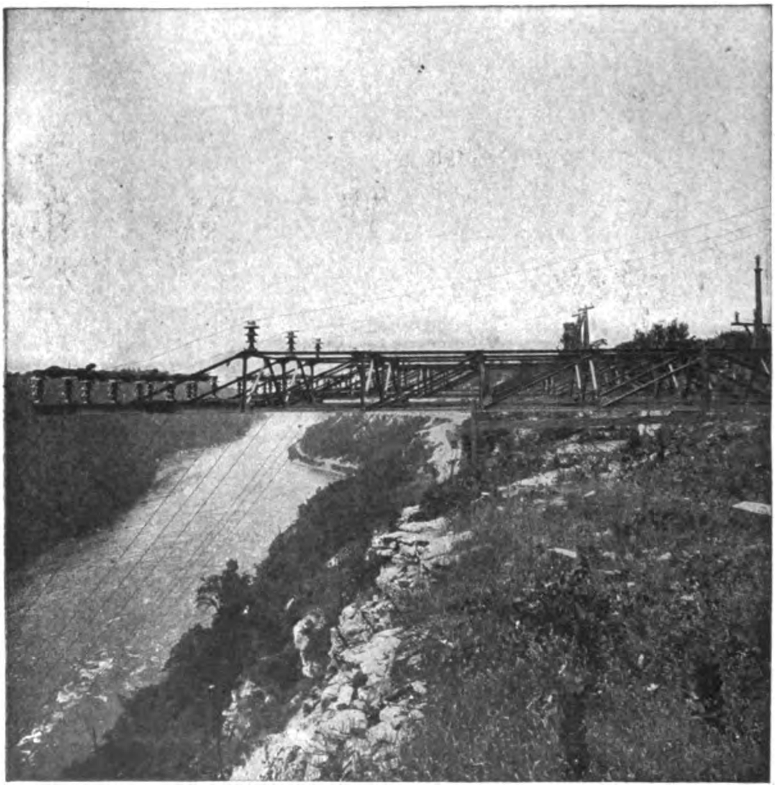

FIG. 4.—Niagara crossing, cantilevers, American side

duplicate. From the Niagara River to Lockport, a distance of 16 miles, there are two lines on the company's private right-of-way, each capable of transmitting 30,000 horse power. From Lockport to Mortimer, a distance of 57 miles, there is a line on the company's private right-of-way having a capacity of 20,000 horse power. From Mortimer east to Syracuse, a distance of 81 miles, there is a line on the company's right-of-way

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having a capacity of 10,000 horse power. From Lockport to a point about 11 miles east and thence south on the company's private right-of-way to the West Shore Railroad, thence on the West Shore Railroad to Pittsford is a line having a capacity of 20,000 horse-power. From Pittsford on the West Shore Railroad

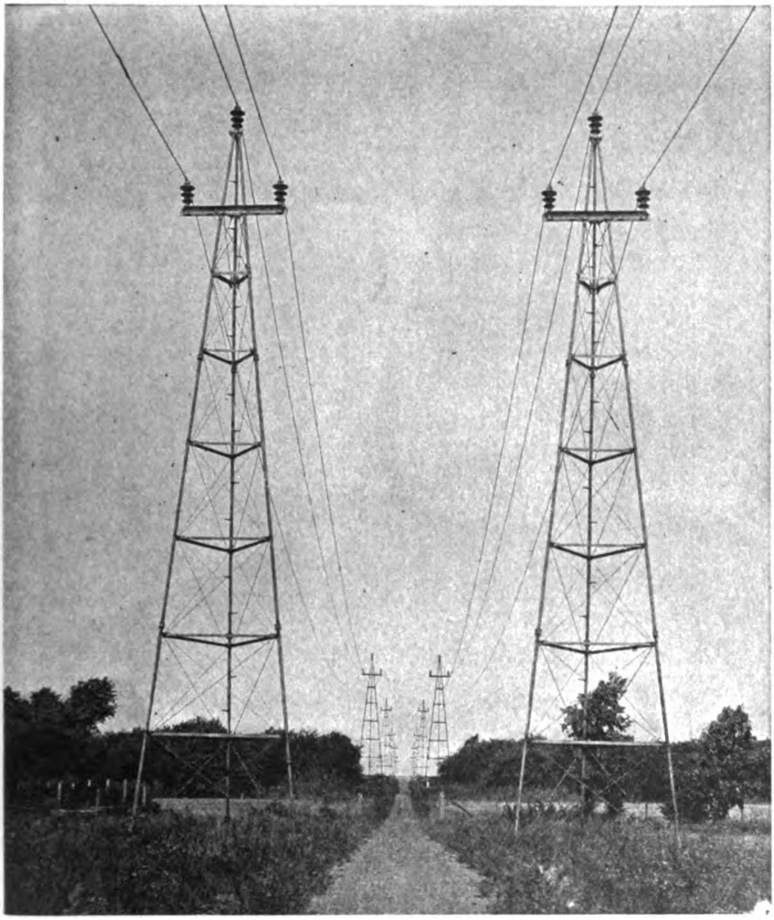

FIG. 5—Pipe towers

right-of-way east to Syracuse is a line having a capacity of 10,000 horse power. From Lockport south to a point south of Buffalo, there are two transmission lines on the private right-of-way of the company, each having a capacity of 30,000 horse power. These two lines south are tapped into the two lines

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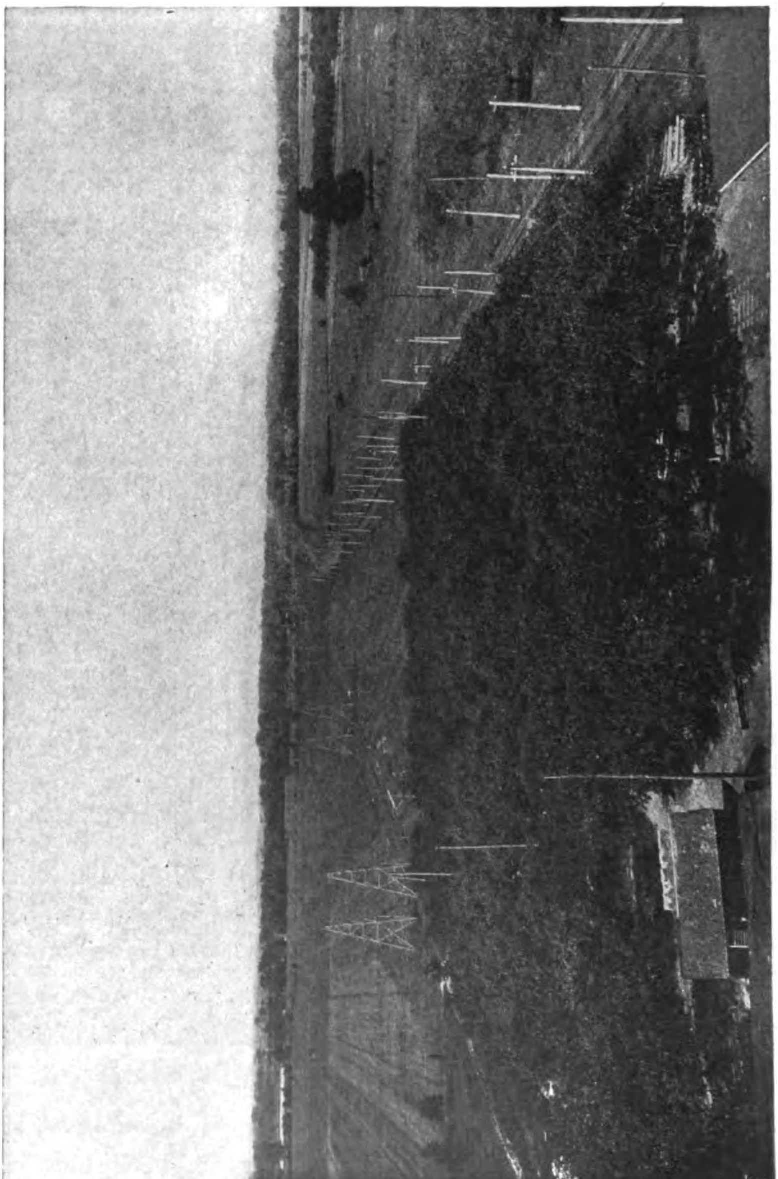

FIG. 6.—Transmission lines from Lockport to Buffalo

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coming from the Niagara River to Lockport, and constitute, therefore, at present, a branch line; but they will be eventually extended clear through to the Niagara River, and it is in anticipation of this extension that they are constructed with the full capacity of 30,000 horse power.. As will be seen from the above, the distance from the Niagara River to Syracuse is 154 miles. In addition to this, the transmission from the trans-

FIG. 7.—950-foot span over Buffalo creek

forming station of the Ontario Power Company to the Niagara River has a length of about 6 miles, making, as previously mentioned, a maximum transmission of 160 miles.

It will be seen, therefore, that in delivering power in Lockport, and in the neighborhood of Buffalo, Rochester, Syracuse, and at intermediate points, the company will have transmission circuits in duplicate, each capable of transmitting the full amount of power to be delivered at the several points.

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As previously stated, the power is brought across the Niagara River by means of aerial cables spanning the river, and delivery of the power is taken by the transmission company at the international boundary line. The cables are brought across the river in three spans, one span from steel cantilevers at the top of the cliff on the Canadian side to steel towers at the water's edge on the Canadian side; another span from the water-edge

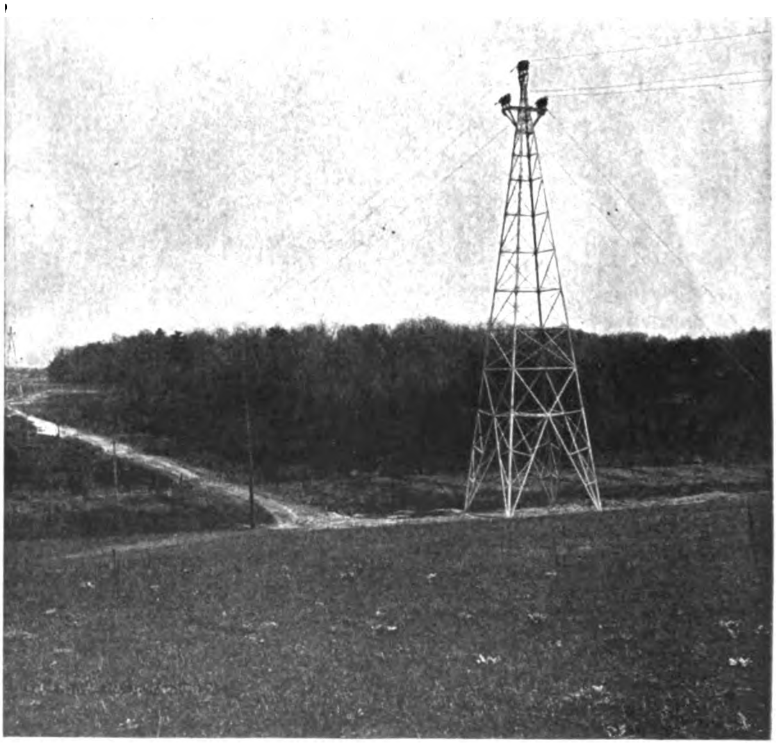

FIG. 8.—1253-foot span over swamp

towers on the Canadian side to the corresponding towers on the American side; and a third span from the steel water-edge towers on the American side to the steel cantilevers at the top of the cliff on the American side. The use of cantilevers is necessitated mainly by reason of the steep angle at which the cable descends from the top of the cliff. Their use also makes possible the required clearance between the cable and the slope of the gorge, a point of special importance on the American

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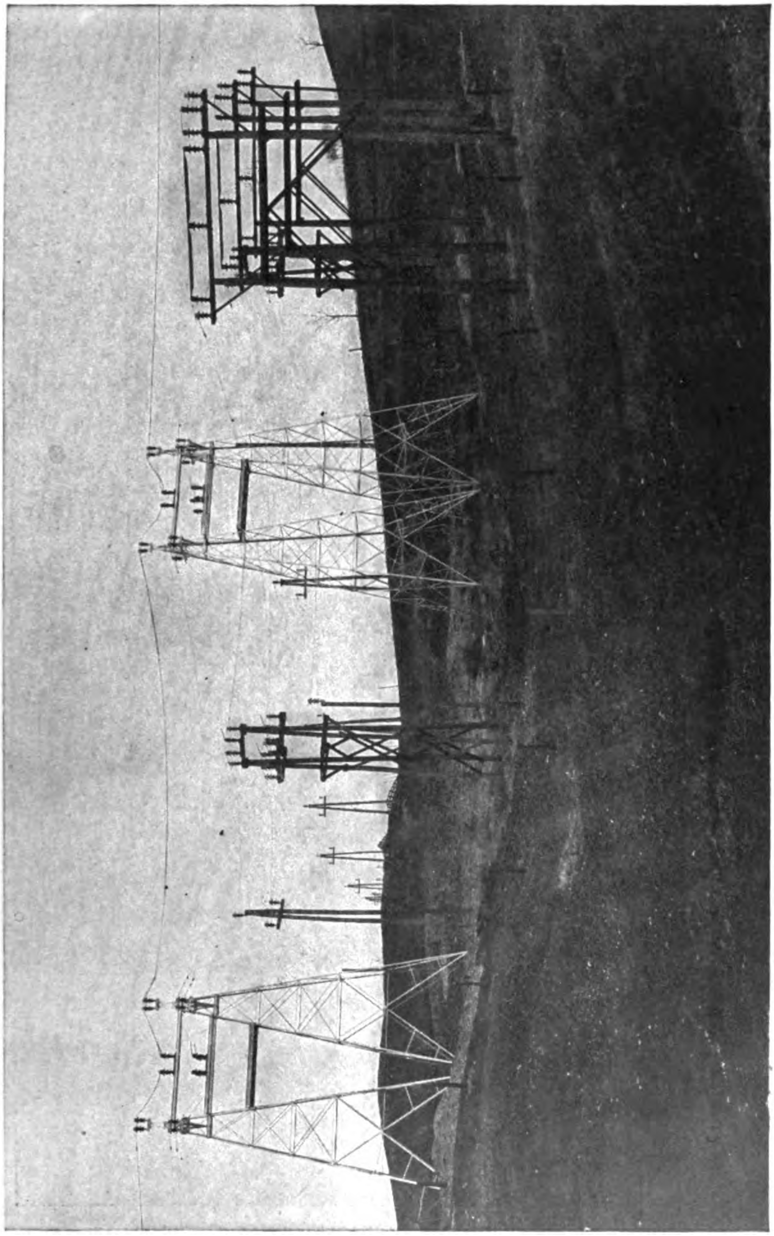

Fig. 9.—Cross-connecting and disconnecting switches and open-air fuses at point of junction of Auburn branch line and the main line

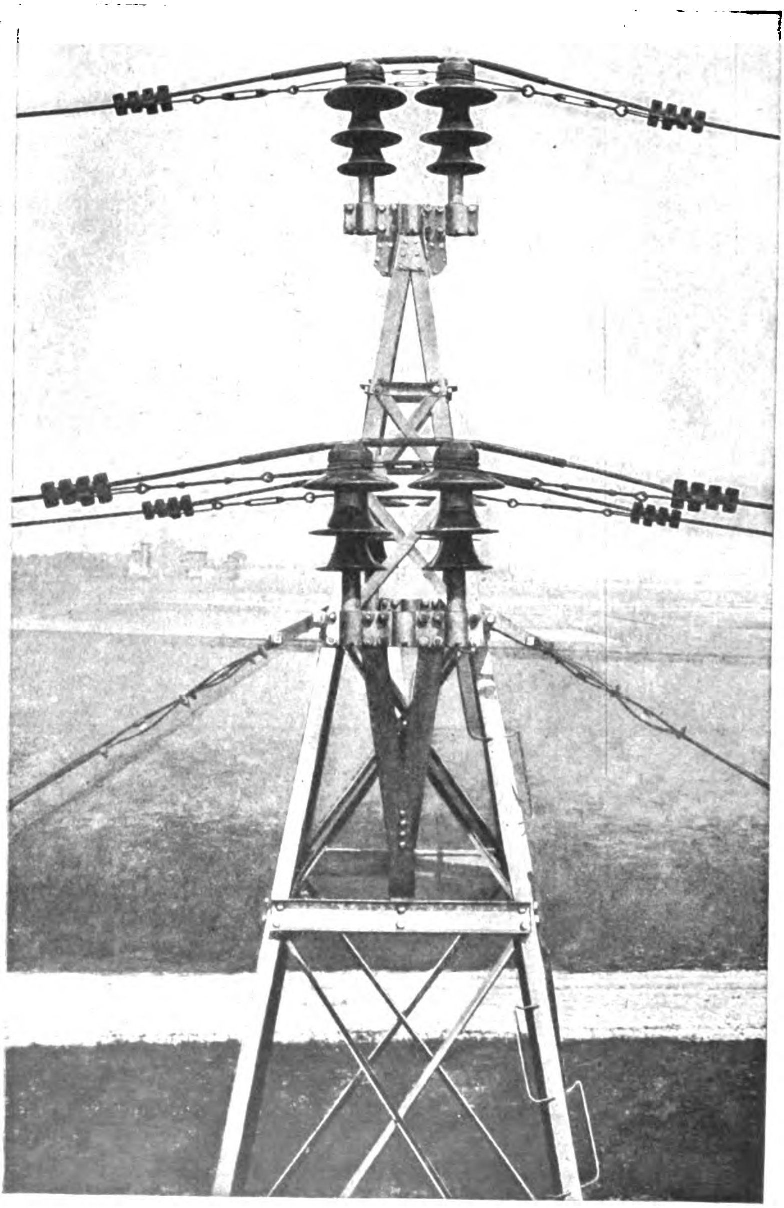

FIG. 10.—Top of double-guyed steel tower

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side in view of the fact that one of the branch lines of the New York Central Railroad is on the American slope of the gorge. The steep slope of the cable at the cantilevers would make it bear upon the upper petticoat of the insulator supporting it,

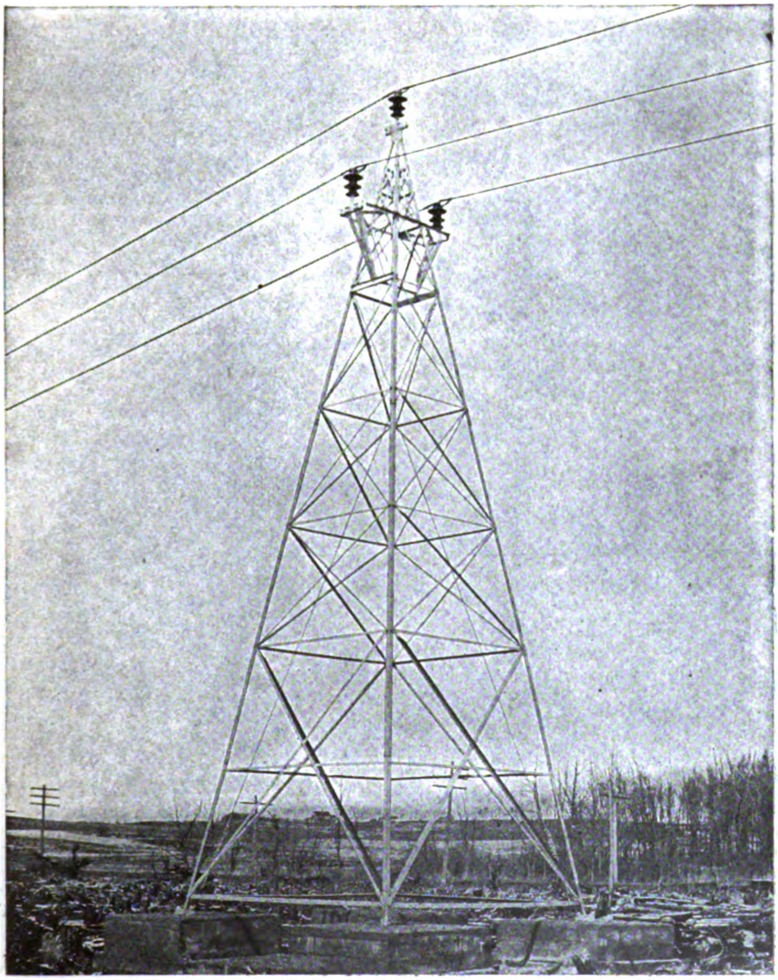

FIG. 11.—Tower in Montezuma swamp

if the cable were attached to the top of the insulator in the usual way. As will be seen by the photographs of the cantilevers, this difficulty is obviated by attaching the cable to a steel cross-bar supported at each end by an insulator.

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The steel cantilevers and the river-edge towers are all designed to withstand the most extreme conditions of sleet and wind that will probably ever exist. The requisite mechanical strength of the insulation at the points where the cables are attached to

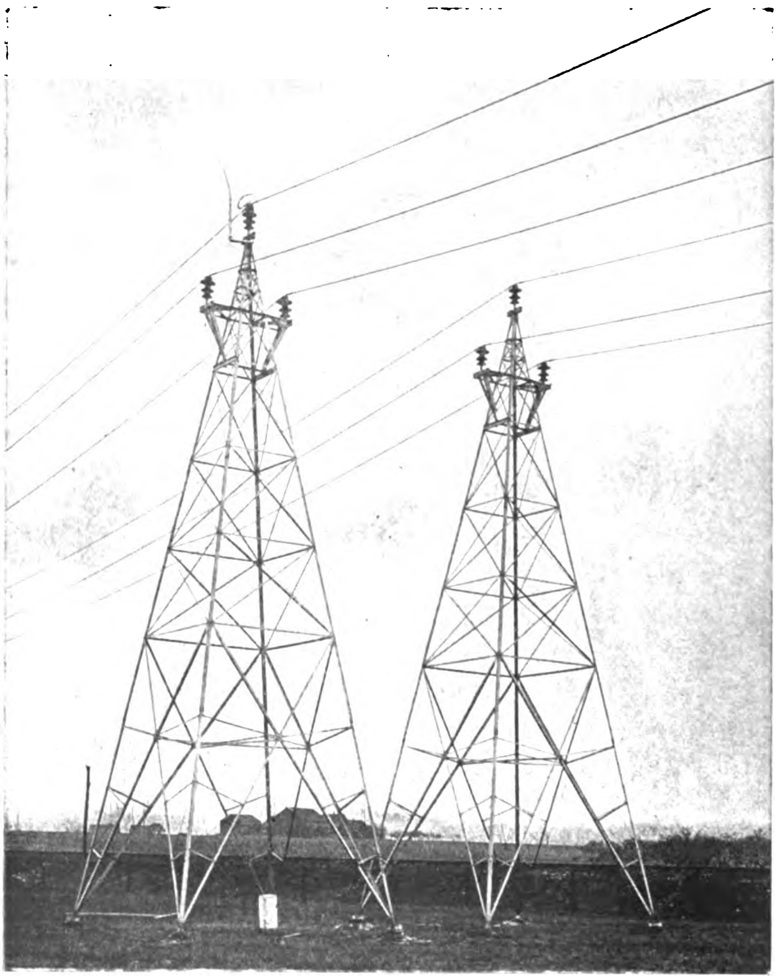

FIG. 12.—Line structure lightning-arrester on steel tower

the steel structures is obtained by using a sufficient number of line insulators, and the proper distribution amongst these insulators of the forces which will come upon them is effected by means of malleable cast-iron caps cemented to the tops of the insulators and to which the cables are fastened.

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It was originally intended, and provided for in the contract with the Ontario Power Company, that just after crossing the river the 60,000-volt lines should be led into a switching station in which, by means of 60,000-volt electrically operated oil-switches, it would be possible to interchange the circuits coming into and going out of this station. The building itself for this switching station has been completed, but, before the equipment of the station had been installed, arrangements were made with the Ontario Power Company to defer the

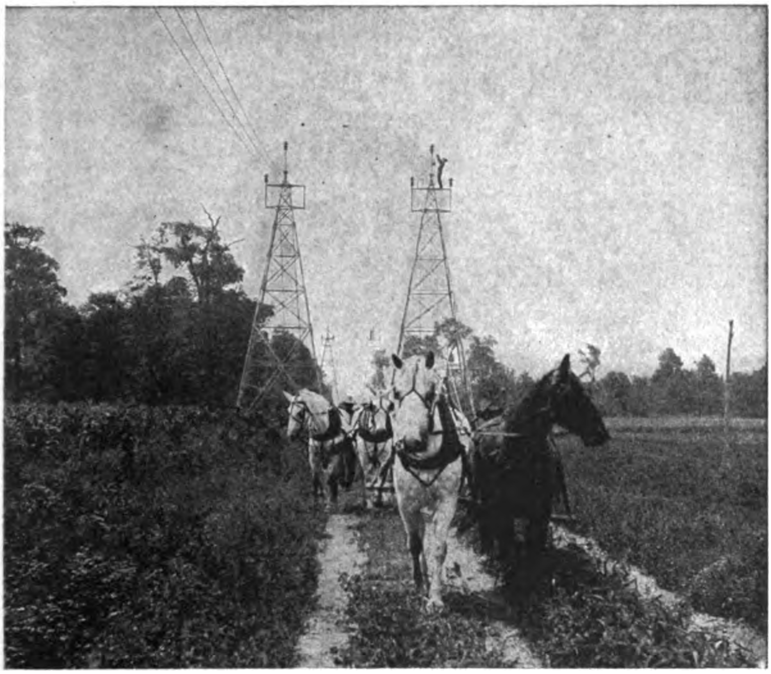

FIG. 13.--Stringing line cable

outlay for such equipment until the use of it should be more necessary than at the present time, when only two lines are in operation.

The main-line construction of the Niagara, Lockport and Ontario Power Company is most substantial. With the exception of that portion of the main line on the West Shore Railroad between Churchville and Syracuse, the main-line structures are all steel towers, and the standard line-span is 550 feet. On some portions of the transmission line, however, much longer spans

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are used, the longest at present installed being 1,253 feet. In some cases these long spans had to be provided with towers heavier than the standard; in other cases it was possible to put them up with little, if any, modification of the standard tower construction. For a number of reasons, the principal one being lack of the requisite space, it was necessary to use on the West Shore right-of-way between Churchville and

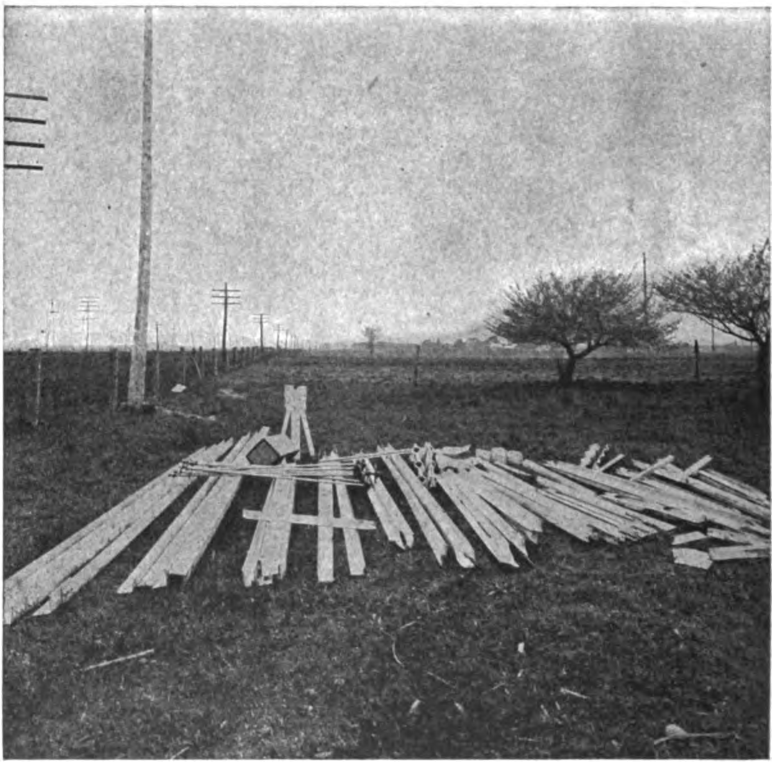

FIG. 14.—Tower delivered ready for assembling

Syracuse wooden construction of special design which will be described later on, the standard span being 220 feet. In every case on the 60,000-volt lines, each line of towers or wooden structures carries only one three-phase circuit. The main line conductors installed so far are all of them of aluminum cable, except on a portion of the line between Mortimer and Syracuse where, because of the long spans employed, it is preferable to use copper.

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The first of the steel towers installed were of the tripod type, made of lap-welded pipe; but the later towers, and those which in the near future will be installed, are of structural shapes and galvanized. The design of these two types of towers is shown in the accompanying illustrations. Two types of the structural tower are shown. The earlier ones were non-interchangeable; that is, the guyed towers differed in construction from the unguyed towers. The later towers are interchangeable; that is, the guyed and unguyed towers are exactly similar except for the guys and double insulators of the former. Contrary to the

FIG. 15.—Assembling tower (1)

practice which has heretofore been followed in the matter of steel line towers, the towers of this transmission line are mounted on foundations of reinforced concrete. These foundations are designed to utilize the weight of the earth around them in resisting uplift. The towers and their foundations are capable of withstanding transverse forces which will be brought upon them when the line cables are covered with 0.5 in. of ice all around them and the wind blowing transverse to the line at a velocity of 75 miles an hour. The towers have the same strength in all directions; that is, they are capable of withstanding the same forces in the direction of the line that they are capable of

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withstanding transverse to the line. To meet the contingency, not likely to occur, of all three cables breaking at once, in which case the full tension of all the cables might be brought upon the towers, there are at intervals along the line certain towers guyed both ways in the direction of the transmission line, and having double fixtures. The strength of these guyed towers is such as would enable them to withstand the forces that

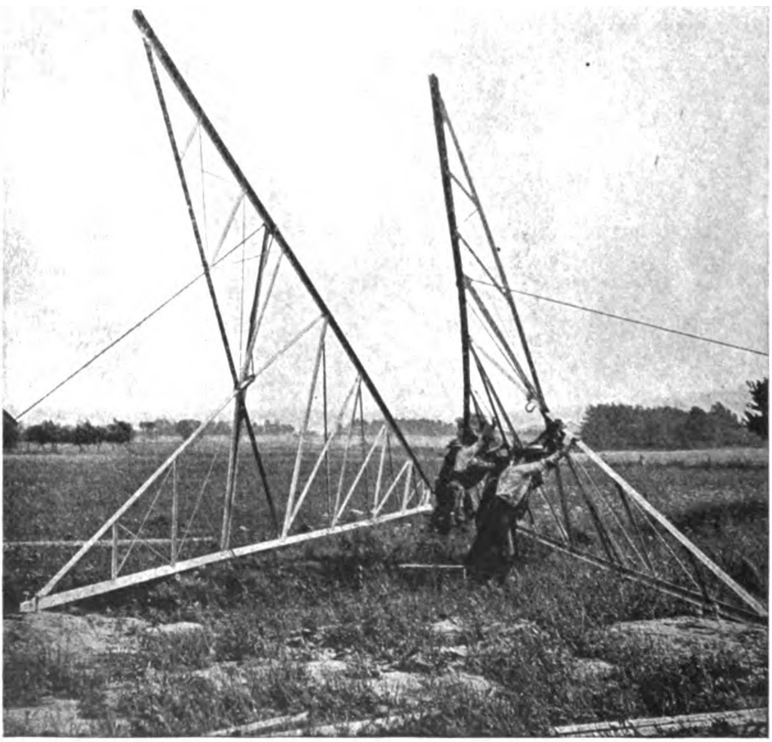

FIG. 16.—Assembling tower (2)

would obtain under the extreme conditions outlined above, if all the line cables should break. The guyed towers will, therefore, terminate any progressive failure of the line which might under extreme conditions be instituted by the breaking of cables.

As stated above, on the West Shore right-of-way it was necessary to use wooden line structures. The type of construction

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employed is that which has been designated by the company as "A-frame construction." It is clearly shown in one of the accompanying cuts. By adopting this type of construction, in which each structure consists of two poles instead of one, it is possible to use twice the length of span that would be used in ordinary wooden pole construction, and employ, therefore, one-half the number of insulators. As stated above, the standard length of span of this type of construction is 220 feet. On

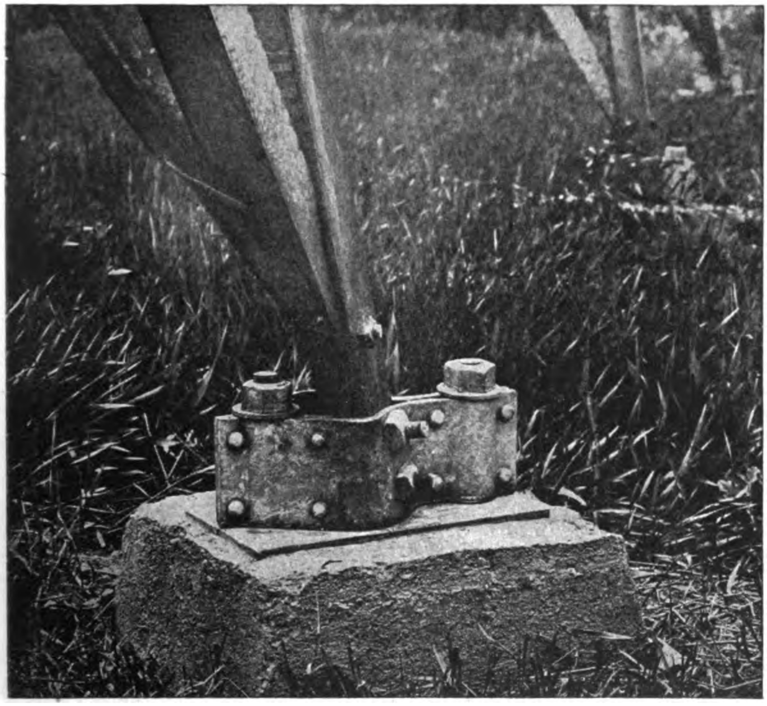

FIG. 17.—Foot of tower, showing method of fastening tower to foundation

some portions of the West Shore right-of-way it was necessary to use steel construction, and in such places there were installed galvanized lattice steel poles, such as are shown in one of the illustrations. The span on these poles is the same as that on the A-frame construction.

In a number of places on the main line, both on the West Shore and on the private right-of-way, it is necessary to cross the Montezuma marsh. Where this marsh was crossed with

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steel tower construction, the concrete foundations for the steel towers were built by first excavating the swamp through the soft mud until the soft marl, forming the sub-stratum of the swamp, was reached. On the marl was laid a platform of two layers of corduroy, and on this platform was built the concrete foundations, the weight of which was made sufficient to take care of any uplift which will come upon the towers. These foundations were installed, some of them, in cold weather and,

FIG. 18.—Tower foundation dug up for purpose of relocation

so far, they have shown no settlement. Where this marsh was crossed with A-frame construction, it was found in places much too expensive to excavate for the proper foundation for the A-frames. The A-frames were, therefore, installed by laying on top of the ground, four line poles in two pairs, the poles of one pair being parallel to the line, and the poles of the other pair being at right angles to the line. These poles were spiked together at the point where they cross, and at the point of crossing the A-frame spiked to them, the A-frame being further

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secured to the poles by braces. On each end of each pair of poles was spiked a box, built up of planking and filled with stone, in order to give sufficient weight to take the uplift due to any pull at the top of the tower. This structure, while far from beautiful, has, so far, proved very satisfactory. The tower construction and the A-frame construction in swamps are shown in the illustrations.

It will be noted that, in some of the illustrations of the towers and A-frames, there is shown a horn attached to a cap on the

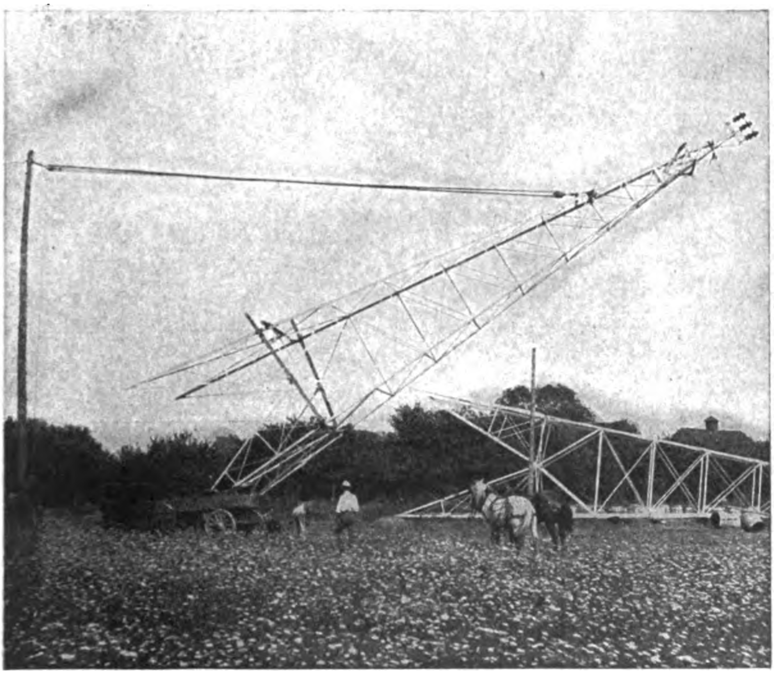

FIG. 19.—Erecting 75-foot tower (1)

top of the insulator and another horn alongside of it fastened to the structure and extending some distance above the insulator. This comprises a combined line structure lightning-arrester, or spark-gap, and lightning-rod. It has been decided to make a careful trial of this method of protection of the line before resorting to a grounded cable; partly because of the great expense of the grounded cable, and partly because there is no reason to think, so far, that it will necessarily afford complete protection in every case. For the present, these line-

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structure lightning-arresters will be installed only on the top cable, in view of the fact that during the last lightning season, in the course of which a number of insulators were broken by lightning, more than three-fourths of the insulators so broken were top insulators.

The insulator used on all the main-line construction is one especially designed for this plant by the writer. It has prob-

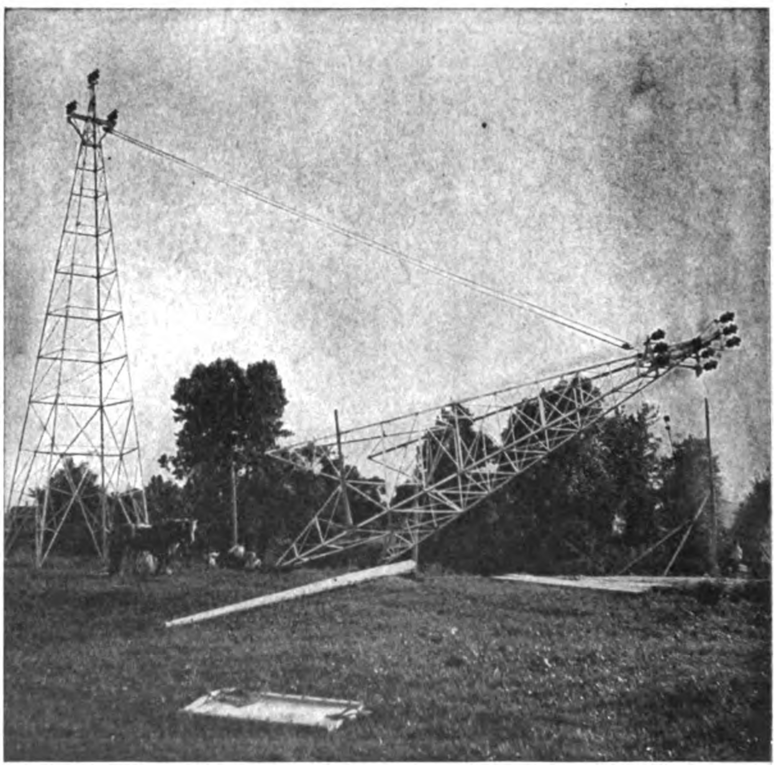

Fig. 20.—Erecting 75-foot tower (2)

ably the greatest factor of safety as regards flashing, etc., of any insulator in practical use to-day, and is considerably larger and heavier than any insulator of which corresponding use has heretofore been made. It consists of three shells nesting in one another and cemented together by means of neat Portland cement, the whole insulator being cemented in a similar manner to a steel pin before attachment to the tower. The insulator is clearly shown in one of the illustrations. The total height

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of it from the edge of the lower petticoat to the top of the head is 19 inches. The diameter of the upper petticoat is 14.5 inches. The insulator used on some of the branch lines is smaller and less expensive than that for the main line, partly because the branch lines receive in general a somewhat lower voltage than the main line and partly because the lines, carrying the small amounts of power they do, are not considered to be entitled

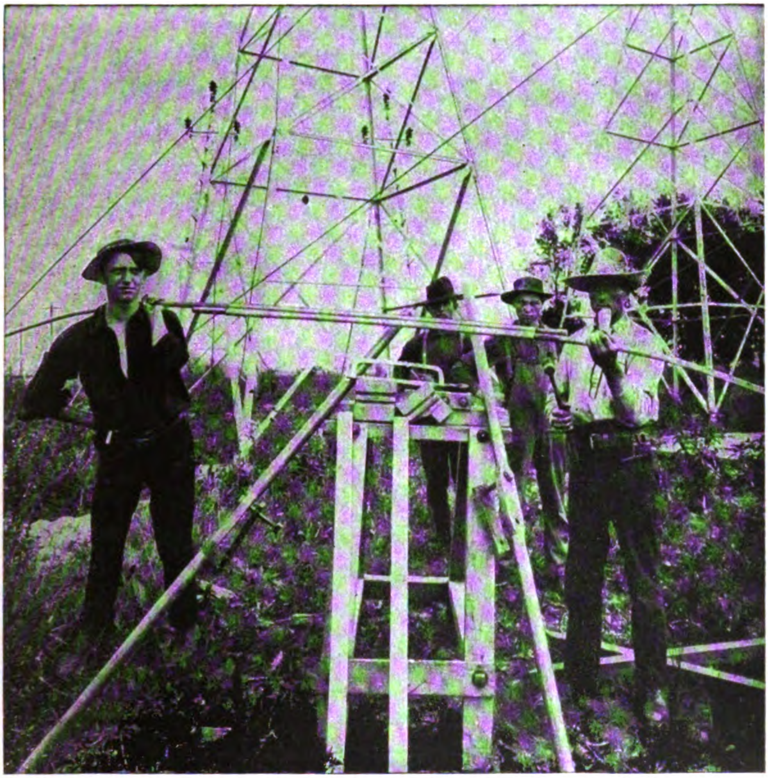

FIG. 21.—The making of a joint (1)

to the same insurance as the main line. Each branch line has in series with it, at the point where it is tapped off the main line, 60,000-volt outdoor fuses to cut out the line in case of trouble on it. The fuses consist of lengths of thin copper wire 16 feet long, run through an ordinary small rubber bath-room hose and laid in clips on top of a wooden bar, supported at each end and at the center by line insulators mounted on poles.

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The fuses are parallel to each other in the same horizontal plane, and the distance from center to center is about 25 feet. These fuses have so far proved very satisfactory but will probably in time be replaced with fuses of the explosion type. The outdoor 60,000-volt fuses are shown in one of the illustrations.

There are only three sizes of cables used on the main transmission line, designated by the company as 3/3, 2/3, and 1/3 respectively. The 3/3 cable is aluminum cable, consisting of

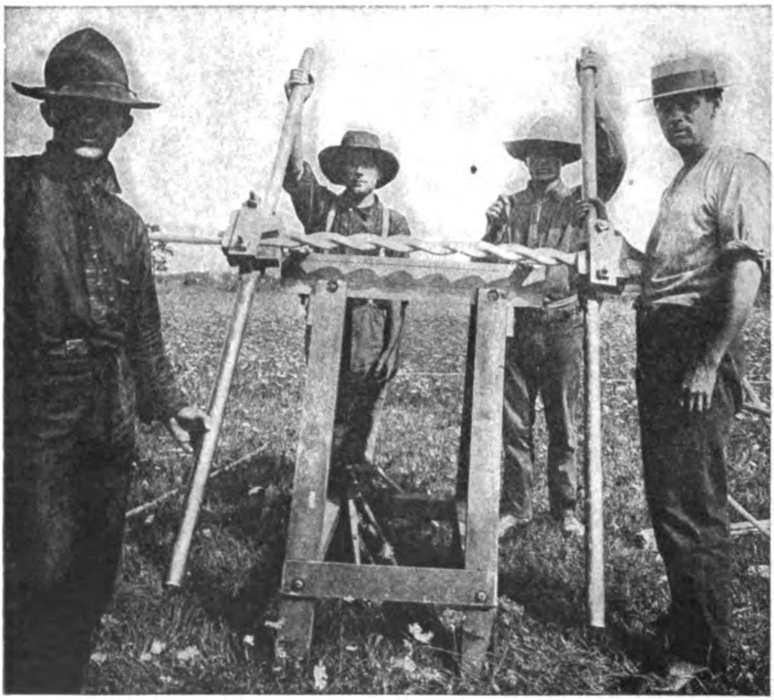

FIG. 22.—The making of a joint (2)

19 strands, and having a total area of 642,800 cir. mils, being equivalent to 400,000 cir. mils copper. The areas of cross-section of the other cables are respectively two-thirds and and one-third that of the large one.

In ordinary straight-away work, the cables lie in the top groove of the insulator, and the pull of the cable is taken care of by means of two aluminum wire ties around the neck of the insulator. One of these ties extends each way along the cable. The tie itself consists of a single loop around the neck of the

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insulator, the two ends of the loop being twisted around the line cable. The result is that the cable is not really fastened to the insulator at all, but simply lies in the top groove. The ties do not, therefore, perform any function, except when there is a pull on the cable tending to slide it in the direction of its

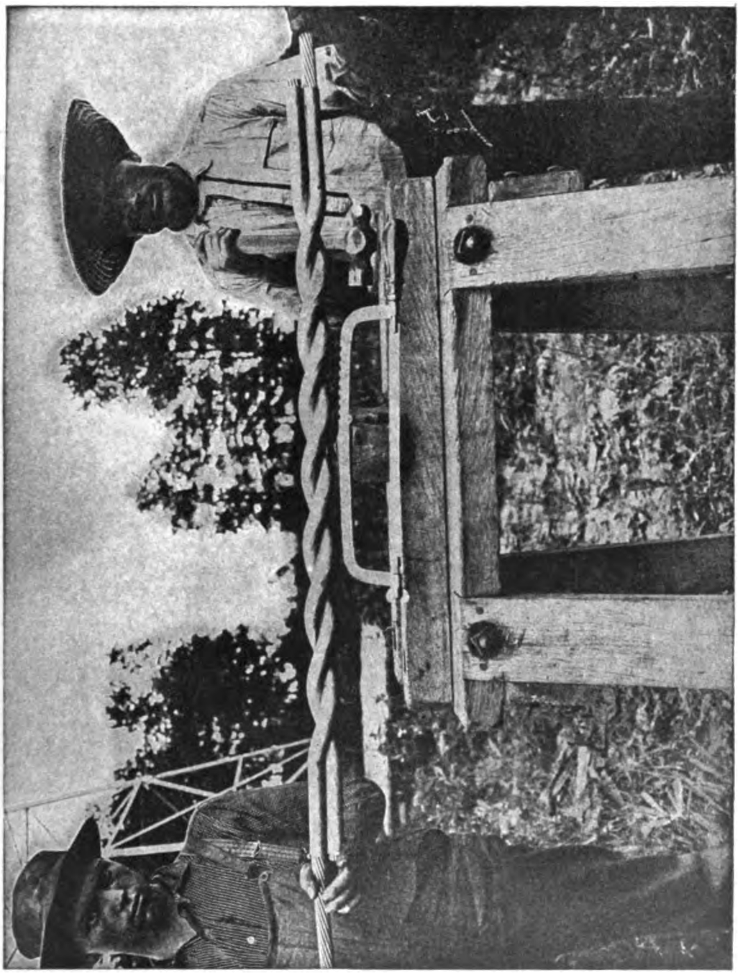

FIG. 23.—**The making of a joint (3) joint complete**

length. The advantage of such a tie is twofold: first; the full strength of the tie wire is developed, which is not the case if a tie is twisted or "pig-tailed," since in such case the tendency is for the tie to cut itself in two at the twist; secondly, the tie does not damage the soft aluminum cable, as would be the case with most of the other ties usually employed.

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In other than straight-away work, and where it is desirable that the method of fastening to the insulator shall be such as will withstand a pull equal to the full strength of the cable, in case the cable should break, the tie mentioned above is not used, but instead there is employed a cable-clamp and a yoke extending each way on the cable.

In every case the cable near the insulator is protected from possible arcs, so that in the event of an arc there will be a chance

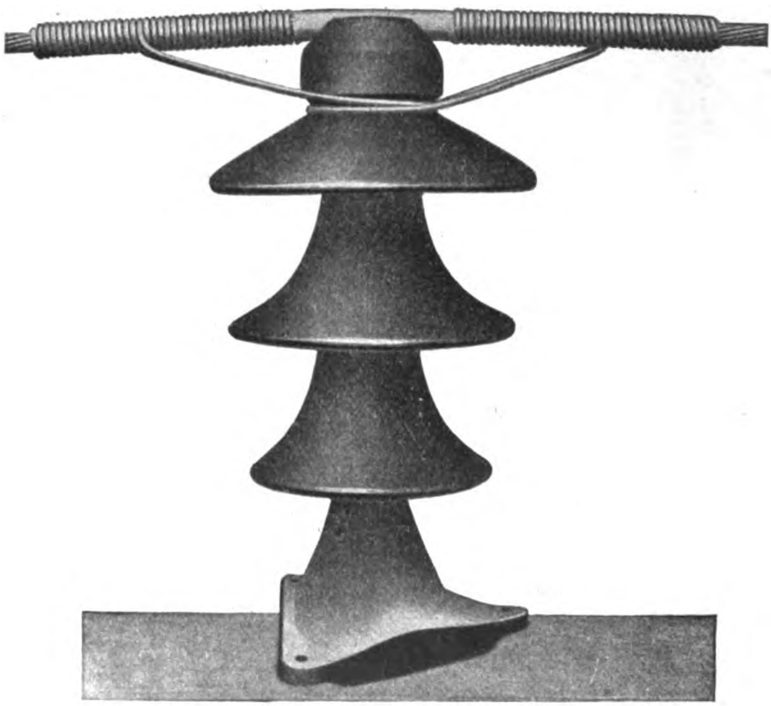

FIG. 24.—60,000-volt main-line insulator with tie and cable protection

for the circuit-breaker at the generating station to open before the cable shall have been burned off. This protection is accomplished in the top groove of the insulator by means of sheet aluminum wrapped around the cable at this point to a thickness of $\frac{1}{8}$ inch, and is accomplished on each side of the head of the insulator to a distance of 12 inches from the head partly by the turns of the tie-wire mentioned above, and partly by an additional serving of tie-wire. Where, in the case of the use of cable-clamps, no tie-wire is used, its absence is made up

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for by additional serving. The photographs show very clearly the methods of attaching the cables to the insulators and the methods of protecting the cables from arcs.

The ends of the line cables are connected by means of twisted-sleeve joints. The method of making these joints is shown in the illustrations.

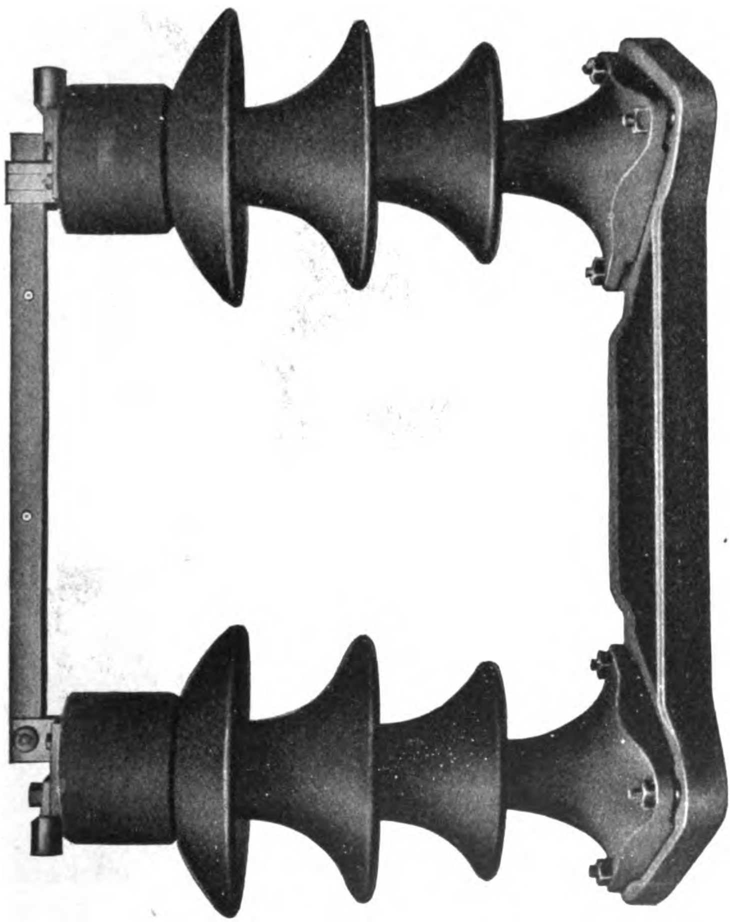

Fig. 25.—60,000-volt outdoor line disconnecting switch

At intervals along the line there are provided disconnecting switches for sectioning the line to facilitate testing out in case of trouble, or cutting out any portion of the line which is damaged. There are also provided at certain points in connection with these disconnecting switches, cross-connecting switches,

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enabling the interconnection of different portions of the two lines.

On a considerable portion of the company's right-of-way is a wagon road, for use in patrolling the line and delivering mate-

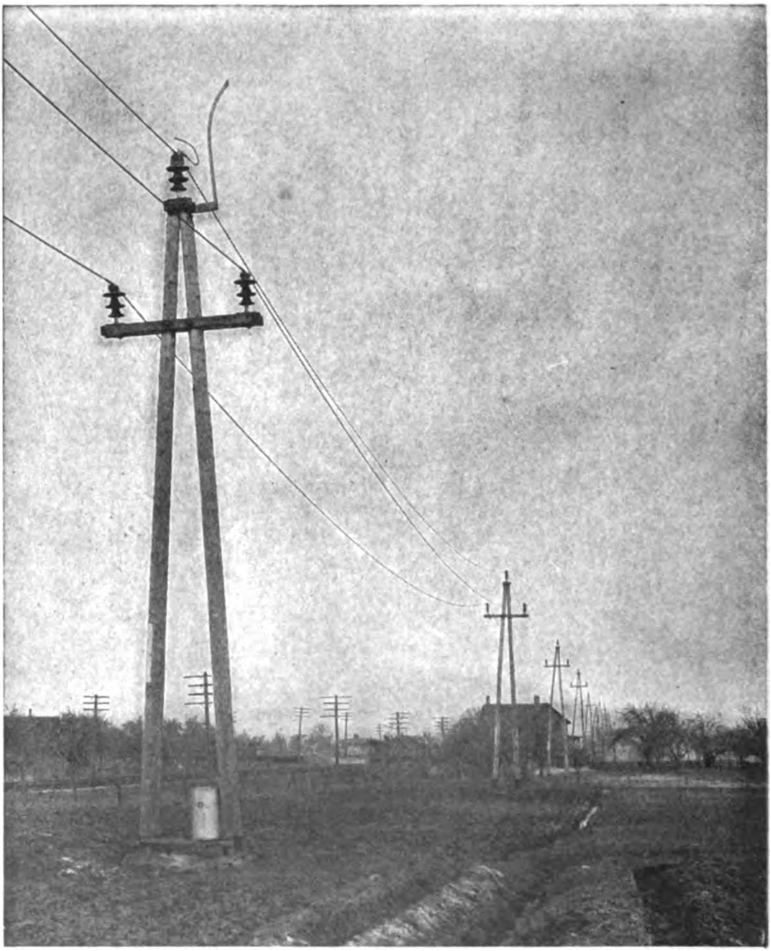

FIG. 26.—Standard A-frame construction showing line structure lightning-arrester

rials for construction or repair. At certain points along the line there are patrol houses for the storage of material, for taking care of teams, and for the comfortable housing of the patrolmen. Each house has in it a sleeping room, kitchen, and

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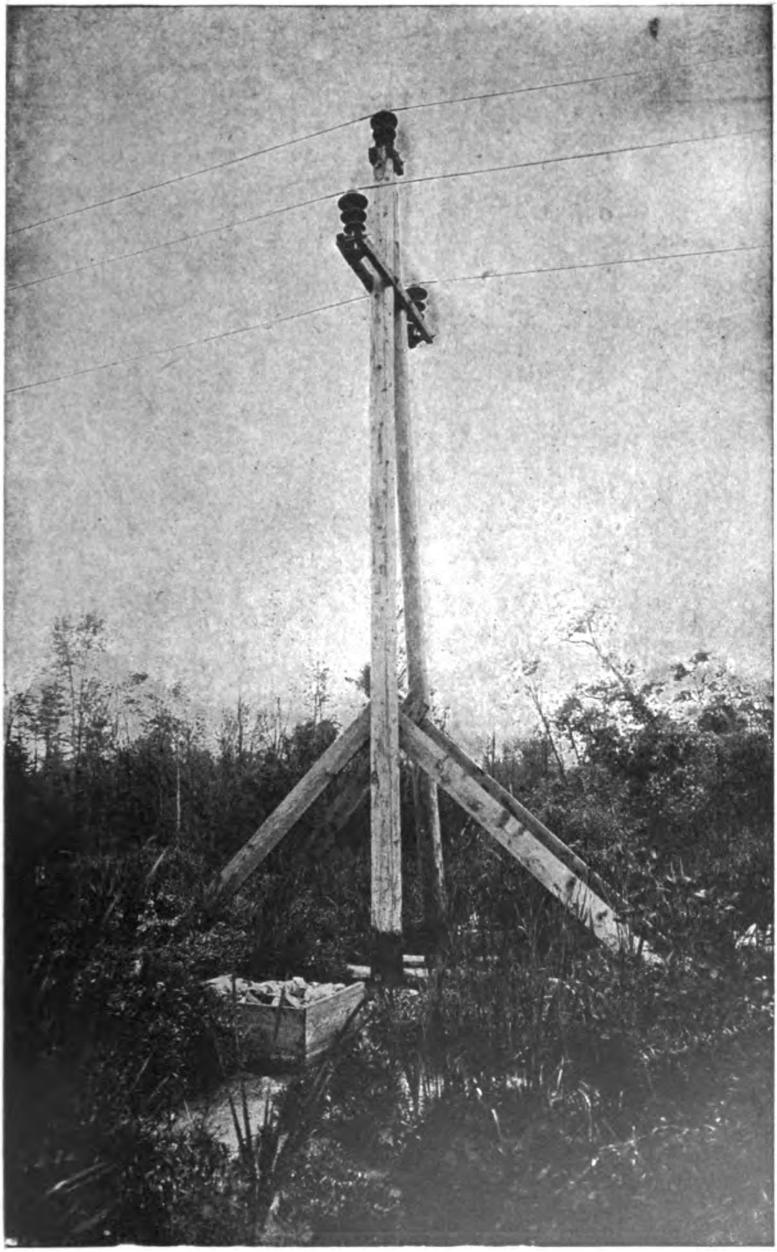

Fig. 27.—A-frame construction Montezuma swamp

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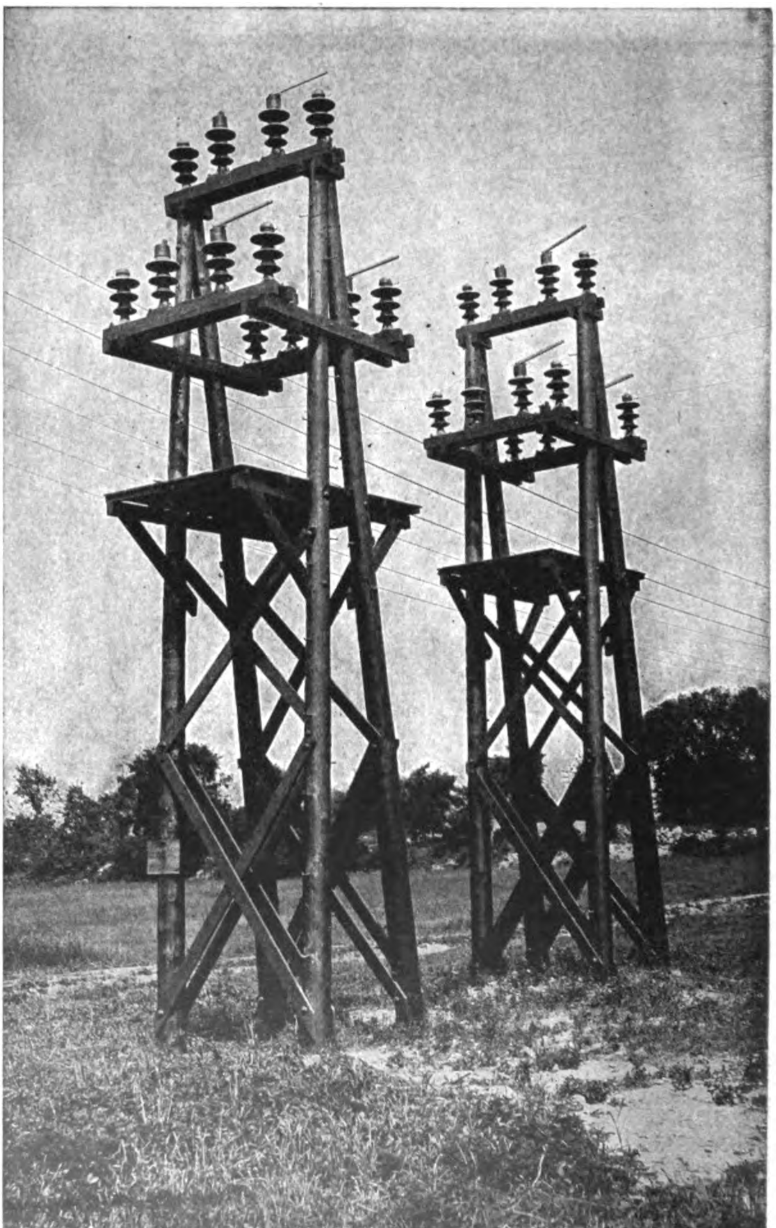

FIG. 28.—A-frame disconnecting switches

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sitting room. On all of the transmission lines, also, the company has a private telephone line on a separate set of wooden poles. Taps from this line are brought into each of the transmission houses, and in addition to this the line patrolmen have

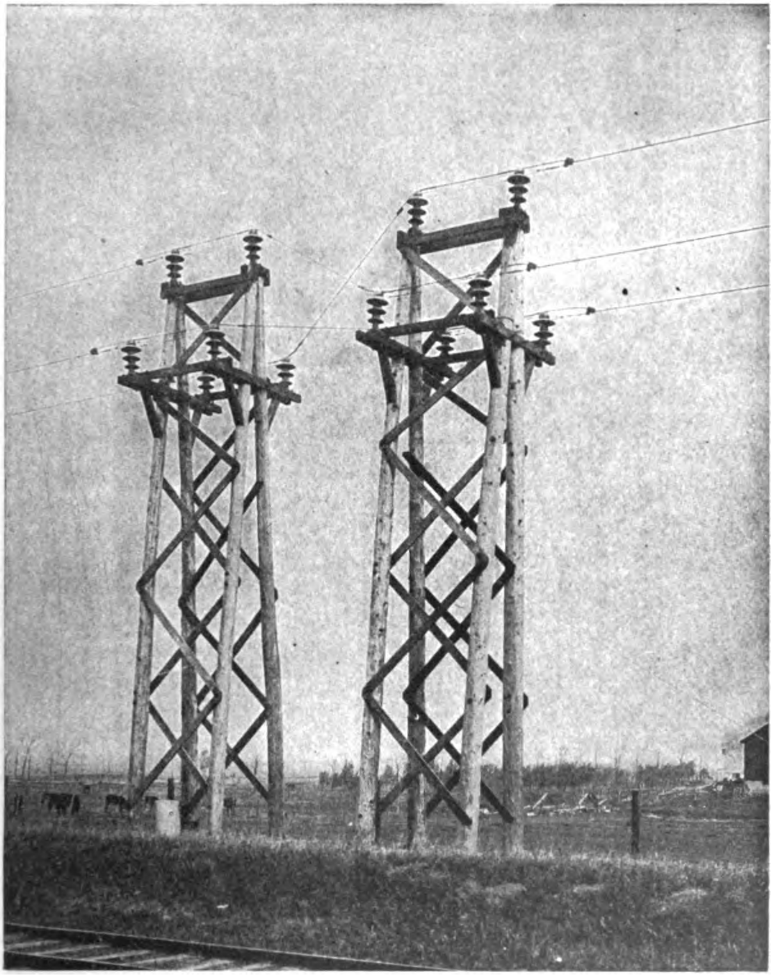

FIG. 29—A-frame transposition

portable telephones which can be connected to the telephone line at any point.

Most of the contracts which the company has for the supply of power cover the delivery of the power at the main-line voltage.

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FIG. 30.—Galvanized steel poles on railway

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Thus far the company has installed only three sub-stations, two of them of considerable size at Lockport and Gardenville, respectively, and one at Baldwinsville, a very small and comparatively inexpensive one. The stations at Lockport and Gardenville have each a normal capacity of 3,000 kw. not including the spare apparatus. They are so designed that their capacity can be indefinitely increased. The Baldwinsville sta-

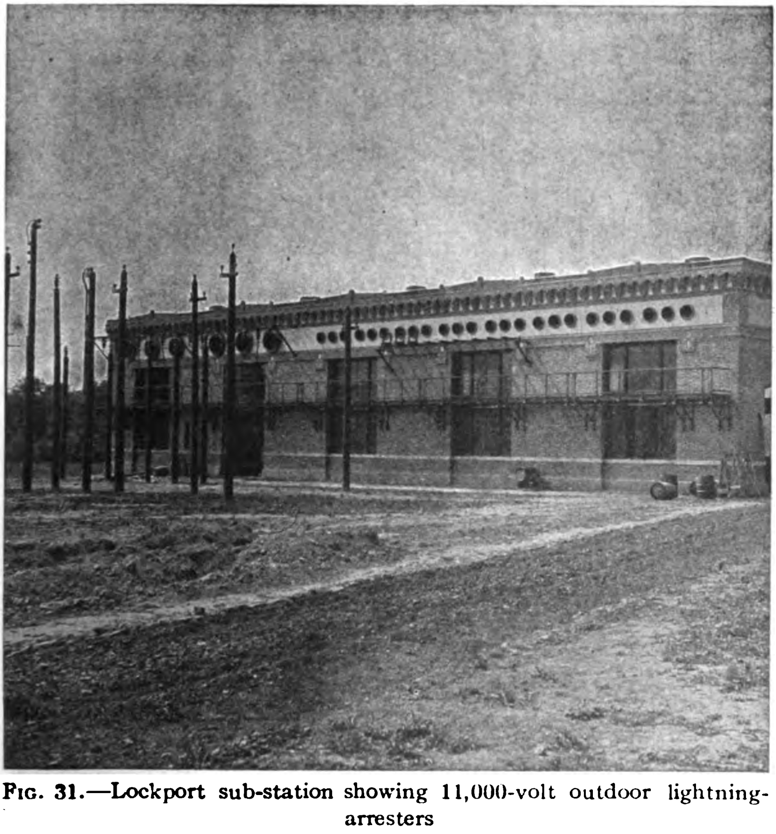

FIG. 31.—Lockport sub-station showing 11,000-volt outdoor lightning-arresters

tion has a capacity of 750 kw. The station at Lockport has been installed and in operation for some time. That at Gardenville is about complete, but not yet in operation. The accompanying illustrations will, in a general way, make clear the type of construction employed in the Lockport and Gardenville sub-stations; but as there are a number of features in connection with these sub-stations which are quite different from ordinary

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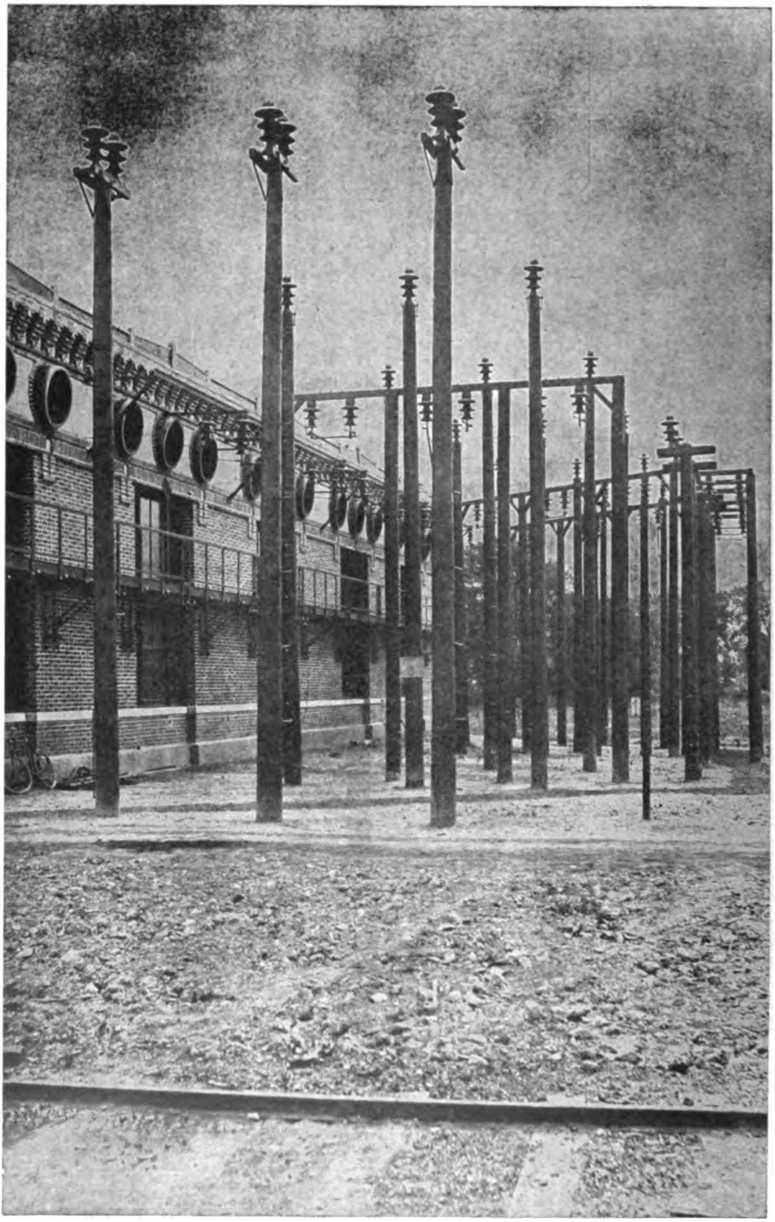

Fig. 32.—Lockport sub-station showing outdoor 60,000-volt bus-bars

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practice in these matters, a brief description of them will be in order.

The 60,000-volt bus-bars at these sub-stations are outdoors; in other words, these bus-bars have been treated exactly as if

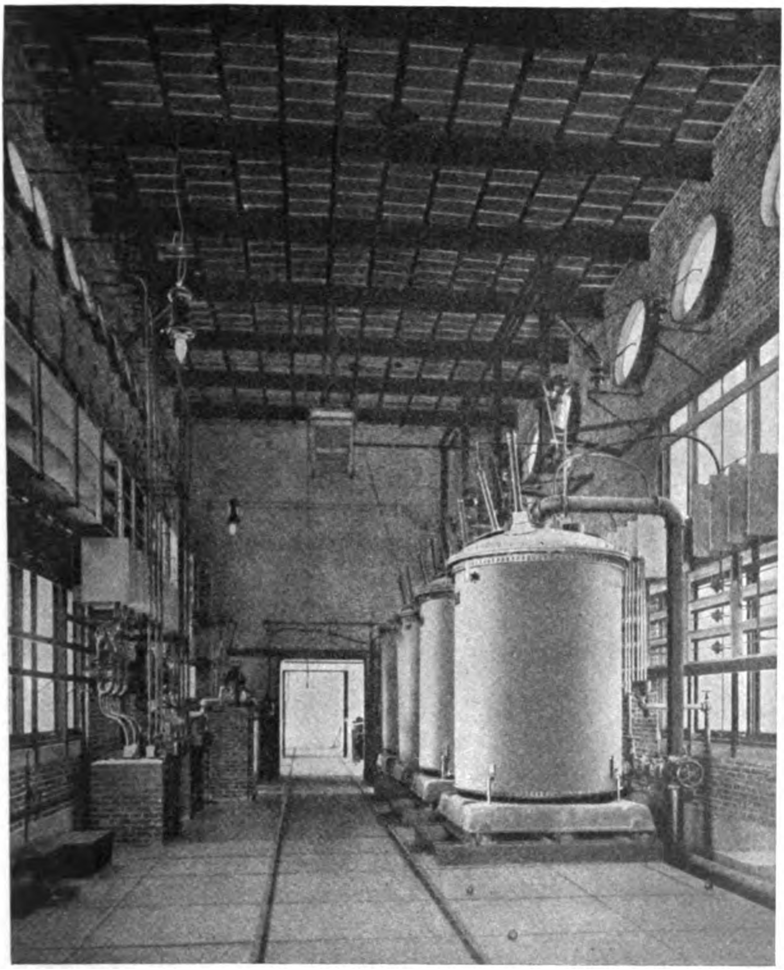

FIG. 33.—Transformer room, Lockport sub-station

they were part of the transmission line and located out of doors in a manner, so far as insulation is concerned, similar to the transmission-line cables. In connection with them are disconnecting switches as shown in the accompanying cut for making various combinations of the apparatus connected to them. Of

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course, the disconnecting switches are not intended to break the working current. When it is necessary to break the circuit under load, it will be accomplished by means of the 60,000-volt electrically operated oil-switches installed in the station which, in the case of the Lockport sub-station, serve also for the control of the two lines to the Buffalo district.

Another feature out of the ordinary in connection with this

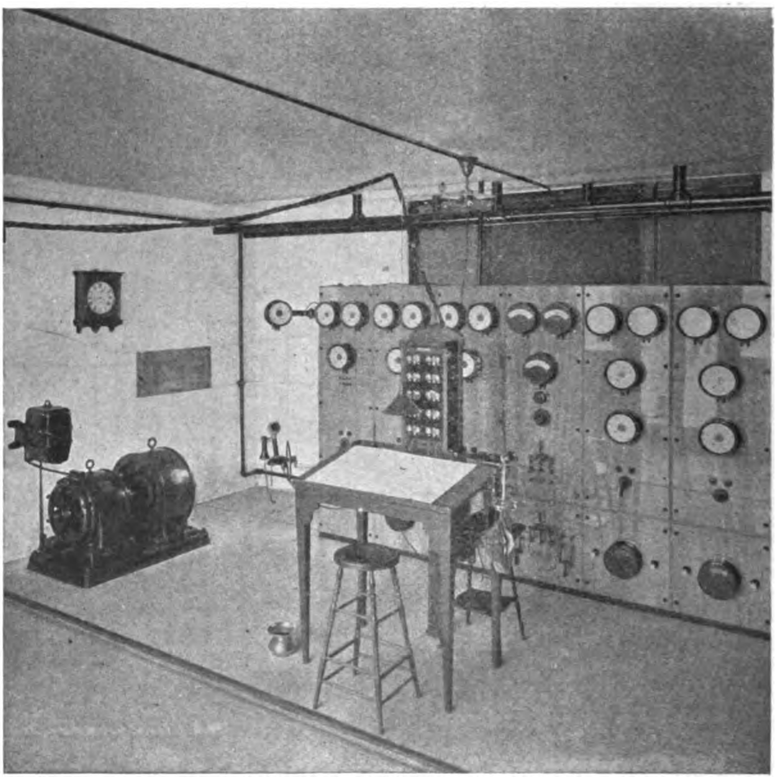

FIG. 34.—Switchboard room, Lockport sub-station

station is the lightning-arrester equipment. This equipment is also out of doors, and consists of a number of horn-type lightning-arresters mounted on wooden poles in much the same manner as such arresters are ordinarily mounted. The installation differs, however, from the ordinary lightning-arrester installation of this kind, for instead of there being only one pair of horns for each line conductor, there are three such pairs. One pair is set for a comparatively low striking electromotive

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force and has in series with it a high resistance; the next pair is set for a higher striking electromotive force, and has in series with it a lower resistance; a third pair is set for very high striking electromotive force and has a fuse in series with it.

The theory on which these arresters are installed is that for ordinary slight static disturbances in the line the arrester having the lower striking electromotive force will discharge, and, since

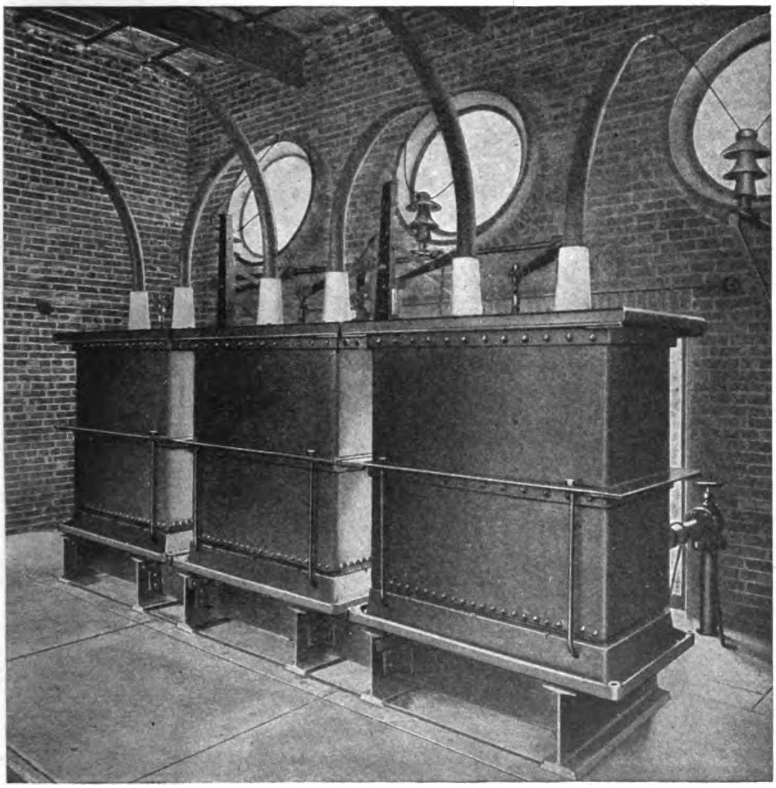

Fig. 35.—60,000-volt oil switch and circuit breaker, electrically operated

it has in series with it a comparatively high resistance, the resultant disturbance to the system due to the generated current which follows the discharge will be comparatively slight. A more severe static disturbance (whether due to lightning or to any other source), will cause both the arrester having the lowest gap and the arrester having the next higher gap to discharge simultaneously, thus affording two discharge paths to earth, the combined resistance and inductance of which is considerably

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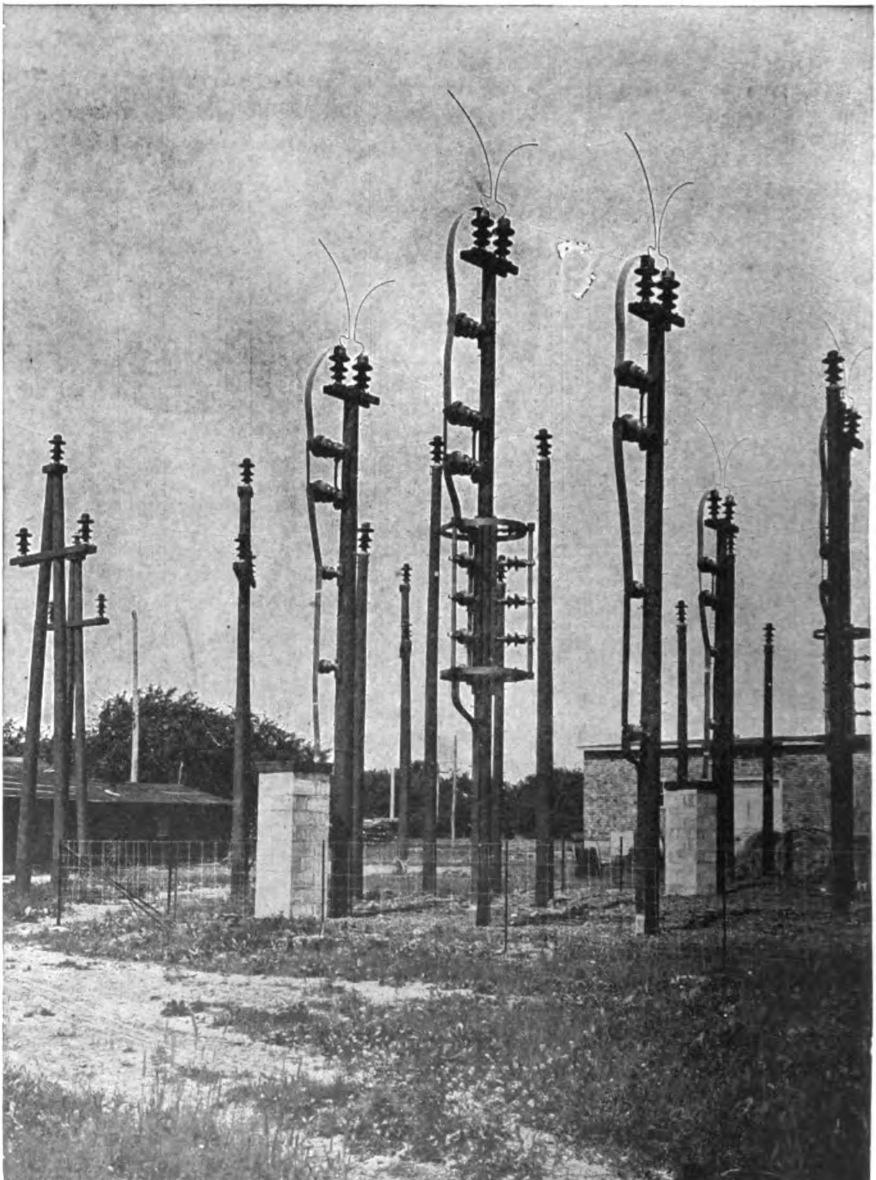

FIG. 36.—60,000-volt lightning-arrester equipment; two 3-phase circuits

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lower than that of the first path. This will mean a somewhat more sevère disturbing effect on the system, due to the generated current which follows. In the case of a very extreme condition; for instance, a direct lightning stroke on the line, the three arresters would discharge simultaneously, the fuse, in the case of the arrester with the highest air-gap, blowing and interrupting the arc upon it, the disturbance of the circuit finally

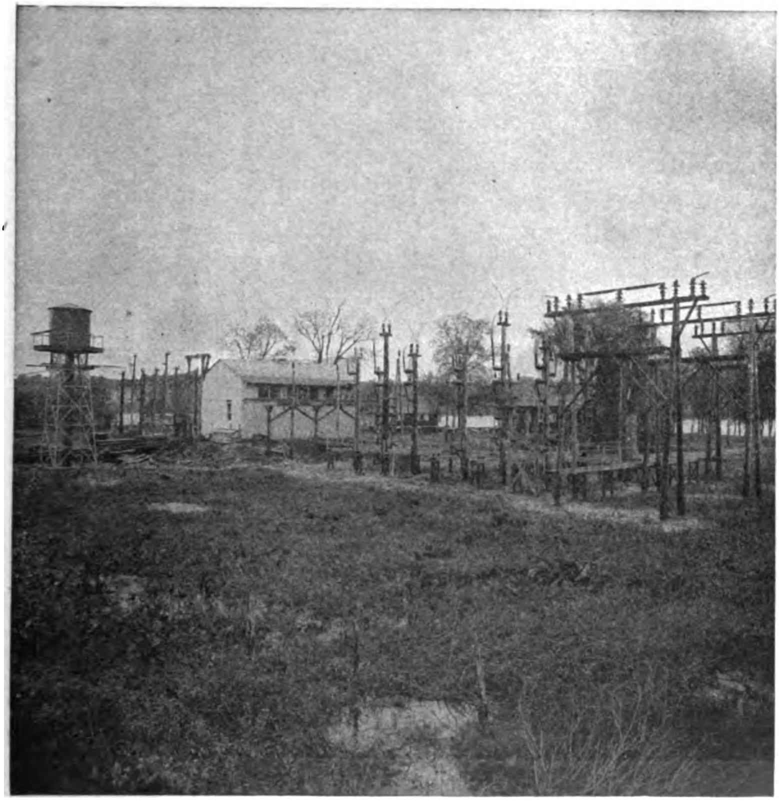

Fig. 37.—Baldwinsville sub-station, showing lightning-arresters

ending upon the other two arresters. Judging from experience in the case of other plants with a much less elaborate arrangement than that outlined, and the experience during the last lightning season with the protection afforded at the Lockport station, the writer believes this method of protection to be entirely effective in the matter of preventing damage to apparatus in the sub-station. Such an installation may, in the case

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of a very severe discharge, such as that due to a direct stroke of lightning, mean a temporary shutdown of the system, or at any rate of the synchronous apparatus operating upon it; but it does not necessarily follow that this will be the case if expulsion fuses be used on the highest gap arrester. Such fuses as have been experimented with in connection with this work operated very satisfactorily. It may be noted in passing that

Fig. 38.—Typical patrol house

a lightning-arrester equipment similar to that just described for sub-stations is installed also at each point where a branch line is taken off at the main line.

The other features of this station are very similar to those usually found in such installations. There is a complete system of oil piping for putting oil into or removing it from the transformers and oil-switches, and also for storing oil, to replace that in the transformers and switches when it may become

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necessary. There is also provided outside of the building an oil-storage tank for storing oil that has been damaged until such time as it is convenient to put it through the oil-cleaning apparatus. In view of the fact that there is no other continuous water supply available at this sub-station, it has been necessary to drill wells for the supply of water for cooling the transformers. In connection with these wells there has been installed a pumping plant, a water tower, and a cooling pond, the latter for use in case the wells should not be able continuously to supply all the water required.

There will be installed shortly on the company's system two switching stations, one at Mortimer and one at Syracuse. The one at Syracuse will be for taking care of the two incoming 10,000-h.p. lines and the outgoing lines to the consumers in Syracuse. The one at Mortimer will be for taking care of the two incoming 20,000-h.p. lines and five outgoing lines, two of them being a line in duplicate to Rochester; two of them the line in duplicate to Syracuse, and one the Avon branch line supplying several installations, amongst them the station of the Erie Railroad Company, operating their trolley line between Rochester and Avon. Both these switching stations will be equipped with the 60,000-volt electrically operated oil-switches, reverse relays, and other apparatus necessary for properly manipulating the circuits which they control.

The transmission lines of this company cross the rights-of-way of a number of railway companies, and some difficulty has been had in arriving at a satisfactory arrangement with the railways in regard to these crossings. In general, the attitude of the railways is that of being unduly fearful of the transmission lines, and requiring protective precautions of one kind or another. It is, however, gratifying to note that in every case the railway companies have, on investigation, been so well satisfied with the reliability of the transmission company's type of line construction as to waive the elaborate steel protective bridges which have been insisted upon at times in the past, and in most cases little or no extra precautions have been required.

The transmission plant has been built in accordance with the designs of the writer, acting as chief engineer of the Niagara, Lockport and Ontario Power Company, and has been constructed under his supervision and that of his assistant in the work, Mr. H. L. St. George.

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A paper presented at a meeting of the Schenectady Branch of the American Institute of Electrical Engineers, Schenectady, N. Y., January 31, 1907.

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LINE CONSTANTS AND ABNORMAL VOLTAGES AND CURRENTS IN HIGH-POTENTIAL TRANSMISSIONS

BY ERNST J. BERG

With a large number of the very high voltage transmission systems being planned at present, the information readily available in regard to capacity, inductance, etc., of transmission lines, is not sufficient to pass upon some of the important questions which necessarily will be brought up. Below are given, therefore, the equations from which these constants can be determined.

$$L = \frac{161}{10^3}\left[2\,{}^{n}lg\,\frac{2D}{d} + \frac{1}{2}\right]$$

where L is inductance per mile of wire (single phase or three phase) expressed in millihenrys; D is the distance between centre of wires;* d is the diameter of wire in same unit as D.

The capacity between one wire and neutral, whether single- or three-phase circuit, is

$$C = \frac{890\,k}{10^4\;{}^{n}lg\,\frac{2D}{d}} = \frac{386\,k}{10^4\;{}^{10}\log\,\frac{2D}{d}}$$

Where C is expressed in microfarads per mile of wire against neutral, D and d in the same units as before. k is the specific inductive capacity, which for air is 1.

Neglecting the quantity $\frac{1}{2}$ inside the parenthesis in the in-

*To be absolutely accurate, D is the distance between the center of one conductor and the surface of the other.

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ductance formula, which is permissible if the distance between the wires is large compared with their diameter, we get

$$L = \frac{742 \, {}^{10}\log \frac{2D}{d}}{10^3}$$

$$C = \frac{386 \, k}{10^4 \, {}^{10}\log \frac{2D}{d}}$$

We see at once that the product of inductance and capacity is constant, regardless of the distance between wires or their diameters;

$$\text{or } L\,C = \frac{286}{10^4}$$

where L is expressed in millihenrys, and C in microfarads, both referring to one mile of wire;

$$\text{or } L_1\,C_1 = \frac{286}{10^{13}}$$

If L_1 and C_1 are expressed in henrys and farads; therefore, if M = number of miles of wire, we get:

$$L'_1\,C'_1 = \frac{286\,M^2}{10^{13}}$$

where L'_1 and C'_1 are the total inductances and capacities of each wire in the system.

The natural period; that is, the frequency at which the system oscillates due to its own constants, depends only upon the inductance and capacity, as long as the resistance is reasonably low so that oscillation can occur.

With concentrated inductance and capacity, it is expressed as $f = \dfrac{1}{2\,\pi\,\sqrt{L\,C}}$.

With distributed capacity, Steinmetz has shown that the frequency is expressed by $\dfrac{1}{4\,\sqrt{L\,C}}$ where L and C are given in henrys and farads.

Since, as shown above, the product $L\,C$ is independent of distances of conductors or their size, it is therefore evident that the natural frequency is also independent of these constants and depends only upon the distance of transmission.

Generally, when discussing the natural frequency of a line, we mean the frequency which the line would have if charged above the ground potential by atmospheric influence, and suddenly relieved of the charge. In this case we should consider the inductance and capacity against ground. These are found by the following equations:

$$L_0 = \frac{2\times 161000\,M}{10_9} \quad {}^{n}lg\,\frac{4\,D}{d}$$

$$C_0 = \frac{178000\,M}{2\times {}^{n}lg \quad \frac{4\,D}{d} \quad 10^{12}}$$

where L_0 and C_0 are given in millihenrys and farads.
M is number of miles of wire; D is distance of the conductor above the ground; d is the diameter of the conductor.

The frequency so obtained is, of course, the same as when using the inductance and capacity between wires. A ready way to determine the natural frequency of the line is to calculate it from the fact that the length of the line constitutes one-quarter of the wave, so that, since the velocity of electrical propagation is the same as that of light, the frequency, for instance, for a line 150 miles long, is

$$\frac{187000}{4\times 150} = 312 \text{ cycles.}$$

It is, of course, important that the fundamental frequency, or that of any prominent harmonic, shall not be the same as the natural period of the line, since, when that is the case, destructive resonance phenomena are likely to happen.

It has hardly been appreciated that, of the higher harmonics, the third cannot exist in a three-phase line, although it is the most prominent in the generator. (Unless the YY connection of transformers is used, which is not good engineering. But even in that case the triple harmonic appears only in the potential against ground, never in the voltage between the lines.) We need, therefore, consider the fifth harmonic more particularly;

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so for instance, in a line 150 miles long, the frequency of the fifth harmonic is obviously five times that of the fundamental. Consequently, in a 60-cycle circuit we have 300 cycles, which is very closely the same as the natural period of the line. 60 cycles would therefore not be feasible unless the line were artificially loaded.

It is perhaps opportune to give an average value of inductance and capacity in high-potential lines. By assuming the inductance as 1.75 millihenrys per mile of wire, and a capacity of 0.0165 mf. per mile of wire, an error of more than 15% can not well be made, when referring to transmissions of from 30,000 to 100,000 volts, and conductors from 0.25 in. to 1 in. in diameter. Since, furthermore, in these high-potential lines it is always necessary to have at least two lines in parallel, it is well to bear in mind that in doing so the ohmic drop is the same, whereas the inductive drop is one half and the charging current is twice as large as with one line. The reactance corresponding to certain inductance is expressed by the following formula:

$$\text{The reactance } x = \frac{2\,\pi\,n\,L}{10^3}$$

The charging current I_0 is expressed by the following formula:

$$I_0 = \frac{2\,\pi\,n C\,E}{10^6}$$

where n is the frequency, L is the inductance in millihenrys, C is the capacity in microfarads, E is the voltage to neutral plain.

If L and C correspond to one mile of wire, x and I_0 obviously also refer to the same.

It is interesting to note in connection with this, that since the voltage to the neutral in a single-phase system is one-half, and in a three-phase system = 0.58 of the line voltage, the charging current per wire for a given line voltage is 16% greater in a three-phase system than in a single-phase system.

With the help of these constants, we can now readily calculate some of the abnormal phenomena.

1. Abnormal Voltage and Current in Opening or Closing a Circuit

To determine this it is necessary to calculate the stored energy. The energy in joules (watt-seconds stored electro-

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magnetically) is $0.5\,L\,I^2$. The energy in joules stored electrostatically is $0.5\,C\,E^2$. Where L and C are given in henrys and farads.

Therefore, if the line is disconnected at the moment the current has a given value I, energy is stored which must be spent in some way. The only path for the current is formed by the line capacity, therefore the line becomes charged to a certain voltage depending upon its constant; next it discharges through the inductance of the line, so charges again, etc. A current oscillates in the system until the energy is dissipated by the resistance of the line. Therefore, with low resistance there will be many surges; with high resistance, few.

The two energy equations become:

$$0.5\,L\,I^2 = 0.5\,C\,E^2 \text{ thus } E = I\sqrt{\frac{L}{C}}$$

$$\text{or } I = E\sqrt{\frac{C}{L}}$$

Substituting the average values given above we get

$$E = 325\,I\text{; and } I = \frac{E}{325}$$

We see from this that the electromotive force induced on opening a circuit is independent of the length of the line.

Opening a switch at full-load instantaneous value of current. In a 60,000 volt transmission of 20,000 kw. the rise will be 60,000 volts per phase; consequently, the total voltage will be almost trebled. Interrupting the charging current will, however, give a very low rise, since the current is so small that there is no difficulty to be anticipated by disconnecting such line.

But, in connecting the line the moment the electromotive force is maximum, *a very considerable instantaneous current will flow,* namely, $\frac{E}{325}$. Consequently, with a voltage between the lines of 60,000, when the voltage per phase is 34,700, the current would be about 100 amperes; whereas the charging current is probably about 10 amperes.

It is also evident from this that we must use such circuit-interrupting devices as open when the current is small, prefer-

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ably zero. From a great number of oscillograms we have found that our oil-switches break at zero value of current, and we find that no rise in voltage will occur when they are used. Indeed, from some oscillograms that have been made in which the circuit has been opened by air-switches, it would seem as if, when the line voltage is sufficiently high, the arc will keep on until the current value is decreased to such a small amount that, at the time of break, there is no serious rise in voltage. A gust of wind might, however, cause the circuit to be broken when the current is large, when, of course, a rise would take place.

It is also interesting to note that, since the rise in voltage is independent of the line voltage, we are likely to have relatively worse stresses with low-voltage systems; although, to be sure, if the voltage is sufficiently low, the likelihood of the current being interrupted at any point but the zero point is slight. These phenomena of large currents and high voltages in a line apply to grounded as well as non-grounded systems.

2. Abnormal Currents and Voltage Stresses in Connecting a Transformer to a System

Outside of the ordinary stresses between adjacent turns, and winding against ground, there is a very high potential stress between the first few turns of the primary winding when the transformer is connected to a live line. The very first instant that connection is made, one part of the winding is raised at line potential, whereas the rest of the winding is still at ground potential. Consequently, the full voltage exists between the first turns. It is therefore necessary to insulate the first few turns extremely well as compared with the succeeding turns.

It is also evident that when being thrown on the line the transformer may sometimes take a much *larger current than the normal exciting current.* If the transformer when last used was disconnected from the circuit when the flux was at its maximum value, the density will decrease after a short time to about 70% of the maximum value, as can be seen by studying the hysteresis loop. If now the transformer is connected to the circuit at such a point of the potential wave as requires increasing flux, the magnetizing current must be very large, since the iron is already at 70% of the saturation point. At the next instant, however, the magnetic condition will adjust itself, so that the current is normal. The first large current

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is, of course, of very short duration, but might well be twenty times the exciting current or two or three times full load.

3. Abnormal Voltage in a Non-Grounded System

There has been a great deal of discussion about grounding or not grounding the neutral of transmission lines. For the very high voltages considered at present, I doubt very much if anything but a grounded system can be considered. When operating at such very high voltages, the difficulties of protecting a transmission, and indeed of building and installing the apparatus, increases materially. In the wiring and line itself, a minimum size of conductor, which already is quite large, is necessary in order to prevent corona effects. This corona involves loss in power and is a likely producer of nitric acid, which is detrimental to adjacent insulation.

Investigation of corona effects in parallel conductors:

Let I = current flowing in conductor.

Magnetomotive force per unit length in zone $= \dfrac{I}{2\pi x}$

field intensity $= 4\pi \times$m.m.f. $= \dfrac{4\pi I}{2\pi x} = \dfrac{2I}{x}$

and magnetic flux in the zone $= \dfrac{2I}{x} \times 1 \times dx$

thus total magnetic flux between wire and zone

$$= \int_r^R 2 I l \frac{dx}{x} = 2 I l\, {}^n lg \frac{R}{r}$$

neglecting flux inside of wire.

thus $L = \dfrac{\text{flux}}{I} = \dfrac{2l}{10^9}\, {}^n lg \dfrac{R}{r}$ henrys.

Therefore we can write the electromotive force corresponding to this flux $E = k\, {}^n lg \dfrac{R}{r}$

The flux between x and R is

$$L_x = 2 l\, {}^n lg \frac{R}{x}$$

and corresponding electromotive force

$$E_x = k\ {}^n lg \frac{R}{x}$$

therefore,

$$\frac{E_x}{E} = \frac{{}^n lg \frac{R}{x}}{{}^n lg \frac{R}{r}}$$

The potential gradient is

$$\frac{d\,Ex}{d\,x} = \frac{1}{x}\ \frac{E}{{}^n lg \frac{R}{r}}$$

Therefore the potential gradient at the surface of the conductor is $S = \dfrac{E}{r\ {}^n lg \frac{R}{r}}$ and at the inside of the outside sphere representing ground potential:

$$S_1 = \frac{E}{R\ {}^n lg \frac{R}{r}}$$

The stress is therefore as much greater at the conductor than at the shell as R is larger than r.

Obviously, when applying this to parallel conductors, we should use as R, one-half the distance between conductors, and as E, the voltage to neutral.

From a number of experiments, it looks as if the maximum stress that can be permitted in air is 100,000 volts per inch. Thus $S = 100{,}000$. Based upon this value we obtain the following voltages of corona:

	No. 10 B&S	No. 4 B&S	No. 000		
	$r=0.05$ in.	$r=0.10$ in.	$r=0.20$ in.	$r=0.5$ in.	$r=1$ in.
R	E	E	E	E	E
5 in	23000	39000	64000	115000	161000
10 in	26500	46000	78000	150000	230000
20 in	30000	53000	92000	184000	300000
50 in	34500	62000	110000	230000	390000
100 in	39000	69000	124000	264000	460000
500 in	46000	85000	156000	345000	620000

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We see, for instance, that in a 60,000-volt ungrounded system, where the potential to ground can readily be 64,000 volts, the smallest wire that could be used in carrying the line through a wall having a hole 10 in. diameter is No. 000 B. & S. Any smaller wire would give corona affects. No. 4 B. & S. would,

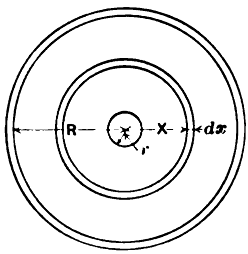

Fig. 1

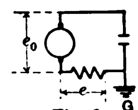

Fig. 2

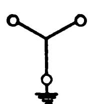

Fig. 3

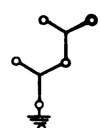

Fig. 4

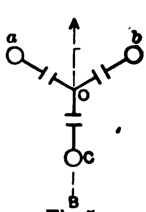

Fig. 5

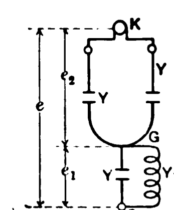

Fig. 6

at the same voltage, require a hole of about 100 in. diameter.

It is also evident that if, as often is the case, the high-potential bus-bars are carried in compartments within but a few inches of ground, we must expect corona effects, especially where there is a sharp bend in the wires, whenever for some reason the volt-

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age is increased above normal. Incidentally, we see the desirability of using large round bus-bars instead of small rectangular bars.

The dielectric strength of insulating materials is greater than that of air, so for instance, from a number of experiments, it seems that insulation of strips of rubber has a strength of about 350,000 volts per inch; oil of about 200,000 volts per inch; and varnished linen or paper between 250,000 and 300,000 volts per inch. It is evident from this that we cannot subject this insulation to higher stress than this without causing deterioration. In the following table is calculated how much insulation is necessary with various sizes of wires and materials of various dielectric strengths.

It is interesting to see that even with rubber insulation we should insulate a wire of 1 in. diameter with about 8 in. of insulation if subjected to 500,000 volts potential to ground. At 300,000 volts we should need 2.27 in. of insulation.

At 150,000 volts we should need 0.68 in. of insulation.

At 60,000 volts we should need 0.20 in. of insulation.

This would give no safety factor whatever. At 500,000 volts the smallest wire that can be insulated is about 1 in. in diameter. At 300,000 volts, 0.5 in. in diameter; at 150,000 volts, 0.20 in. diameter; and 60,000 volts, a very small wire.

But limiting the stress to 140,000 volts per inch we find that:

For 500,000 volts the wire should be more than 2 in. in diameter.
300,000 volts the wire should be about 2 in. in diameter.
150,000 volts the wire should be just a little less than 1 in. in diameter.
60,000 volts the wire should be 0.20 in. No. 000 B. & S.
30,000 volts the wire should be 0.10 in. or No. 10 B. & S.

It is evident from this that it is very essential to keep the maximum voltage down when considering voltages from 60,000 to 100,000 volts. By grounding the neutral we limit this to 58% of the voltage between lines.

Apparent erratic voltage between terminal and ground. When measuring the voltage between any of the terminals and ground, it is observed that it is not definite but depends, essentially upon the resistance in the circuit. This, however, is natural, as can be seen from the following reasoning:

Let e be the voltage from terminal to ground; that is, the voltage across the resistance.

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THICKNESS OF INSULATION IN INCHES WITH VARIOUS STRESSES AT SURFACE OF CONDUCTOR

r	$S=70{,}000$	$S=140{,}000$	$S=200{,}000$	$S=350{,}000$
	500,000 VOLTS TO GROUND			
0.05	5×10^{59}	5×10^{28}	2506×10^{16}	1256×10^{6}
0.10	1×10^{29}	3163×10^{10}	708×10^{6}	158500
0.20	6325×10^{10}	1125×10^{3}	53220	251.6
0.50	792400	628.9	73.46	8.189
1.00	1258	34.49	11.16	3.169
	300,000 VOLTS TO GROUND			
0.05	7925×10^{31}	1991×10^{13}	5236×10^{7}	1377000
0.10	3981×10^{12}	1995×10^{4}	322500	324.8
0.20	3991×10^{4}	8934	3598	14.29
0.50	2623.5	35.72	9.7	2.273
1.00	71.45	7.512	3.478	1.355
	150,000 VOLTS TO GROUND			
0.05	1991×10^{13}	99760000	161800	262.4
0.10	1995×10^{4}	4666	179.8	7.1444
0.20	8934	42.07	8.283	1.502
0.50	35.72	3.755	1.739	0.677
1.00	7.512	1.918	1.112	0.535
	60,000 VOLTS TO GROUND			
0.05	1380000	263	20.04	1.488
0.10	325	7.15	1.904	0.4546
0.20	14.3	1.5	0.6954	0.271
0.50	2.28	0.68	0.4108	0.2043
1.00	1.35	0.54	0.35	0.187
	30,000 VOLTS TO GROUND			
0.05	263	3.6	0.9525	0.2273
0.10	7.15	0.752	0.34477	0.1355
0.20	1.5	0.384	0.2232	0.1041
0.50	0.68	0.27	0.1748	0.0934
1.00	0.54	0.24	0.162	0.09
	15,000 VOLTS TO GROUND			
0.05	3.6	0.37		
0.10	0.752	0.192		
0.20	0.384	0.14		
0.50	0.27	0.12		
1.00	0.24	0.11		

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e_0 be the generator voltage per phase,
x = capacity reactance of the system,
r = the resistance between the capacity and the terminal.
We have then:

$$\text{current flowing} = \frac{e_0}{r + j\,x}$$

and voltage across the resistance:

$$e = \frac{e_0\,r}{r - j\,x} = \frac{e_0\,r}{\sqrt{r^2 + x^2}}$$

With a generator disconnected from any line, the charging current against ground is, of course, very slight, so that x is very large. Therefore for moderate values of r, compared with the values of x, we see that changing the resistance does not materially change the denominator, but the voltage e is proportional to the resistance; thus there is a constant-current effect. The more resistance is put in circuit the higher is the voltage. With infinite resistance the voltage is

$$\frac{e_0}{\sqrt{3}} = 0.58\,e_0$$

Effect of slight leaks in switches, etc. Assume next that the terminal of one phase through a slight leak is connected to ground; the voltage between the other phases and ground will then be almost doubled, being $e\sqrt{3}$

If there are two sets of generators running independently, and there is a slight leak from one terminal of one to that of the other, and also a slight leak to ground, there will be at times 3.5 times as great potential to ground as when the neutral is grounded. This condition might well occur when synchronizing machines or transformers. In circuits of moderate voltage, these voltages might not cause undue stresses, but with a noimal voltage of 100,000 it is quite different.

But grounding a terminal does not always give the same results. A positive "good" ground does not cause the "statics" of an arcing ground. The reason is as follows: no matter how or where the circuit is made, as long as there is an arc there is a circuit. Usually this contains resistance, reactance, and capacity.

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With a positive ground, the frequency impressed is that of the generator, and it would be but a chance if the values of capacity and reactance should be such as to cause more than slight resonance. With an arcing ground, on the contrary, the circuit is disconnected, and can, and will, oscillate at its own frequency, which is such as to give resonance, which means such as to give the maximum voltage and current.

To be sure, if, as in our lightning-arrester, the oscillations are damped out by a judicious use of resistance, no dangerous voltages occur; but with accidental slight leaks or grounds, it is quite different. The voltages from ground might then be almost anything. Some protection is, of course, to limit the rise by grounded neutral.

In an ungrounded system, grave danger exists under almost all conditions of disturbed service. For instance, a lightning stroke disables some apparatus so that inductance is introduced in the accidental ground. Before the accident we had a perfectly balanced system, where the neutral, or ground potential, is symmetrical in reference to the line conductors, and governed entirely by the ground capacities represented in Fig. 5 as three condensers. If now one line is grounded by an impedance, the neutral will be displaced along line AB.

For convenience in demonstrating, we can change the diagram to a single-phase system, making due allowance, however, in the final conclusions—we will reconstruct the system to another shown in Fig. 6.

Let Y represent the admittance of each condenser, Y_1 the admittance of the impedance connected to ground, which is electrostatically the same as connecting impedance between the line and the point of neutral potential.

We have then the joint admittance between C and G = $Y + Y_1$, therefore the joint impedance $\frac{1}{Y + Y_1}$. The joint admittance between G and K is $2Y$, therefore the corresponding impedance is $\frac{1Y}{2}$. The total impedance is therefore:

$$\frac{1}{Y+Y_1} + \frac{1}{2Y} = \frac{3Y+Y_1}{2Y(Y+Y_1)}$$

The current is therefore, $\frac{2eY(Y+Y_1)}{3\,Y+Y}$

$$E_1 = \frac{2EY(Y+Y_1)}{3Y+Y_1} \frac{1}{Y+Y_1} = \frac{3Y+Y}{2eY}$$

$$E_2 = \frac{2eY(Y+Y_1)}{3Y+Y_1} \frac{1}{2Y} = \frac{e(Y+Y_1)}{3Y+Y_1}$$

$Y = g - jb$, where g is energy component of current; b is wattless component of the current in the condenser.

$$Y_1 = \frac{r}{Z^2} + \frac{jx}{Z^2}$$

where r is energy component of electromotive force and x is wattless component of electromotive force.

We will assume that there is no leakage in the line, therefore $g = 0$ and $Y = -jb$.

We will also assume that there is no resistance, but only reactance in the accidental ground of the line.

Thus $r = 0$ and $Y_1 = j\frac{1}{x}$

We get then $e_1 = \dfrac{2be}{3b - \dfrac{1}{x}}$ and $e_2 = \dfrac{\dfrac{1}{x} - b}{\dfrac{1}{x} - 3b} e$

If x_1 = condenser reactance, then

$$e_1 = \frac{2ex}{3x - x_1} \text{ and } e_2 = \frac{x_1 - x}{x_1 - 3x} e$$

1. Ground made by infinite reactance. (No ground.)

We have then $x = \infty$, $e_1 = \dfrac{2e}{3}$ and $e_2 = \dfrac{e}{3}$

Therefore in our diagram, the neutral lies at O, and the ground is symmetrical in reference to the three lines.

2. $\dfrac{1}{x} = b$, thus $e_2 = 0$, and $e_1 = e$.

In this case the neutral lies midways between the two other conductors, and 0.870 from the grounded line.

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3. For $\frac{1}{x} = 3\,b\,e_1$ and e_2 both become infinite showing that, under such condition, the system would be subjected to infinite potential.

b is the susceptance of the condenser, therefore $\frac{1}{b}$ is the condensance or capacity reactance. We see, therefore, if one line is grounded by a reactance of one-third the condenser reactance, the system is subjected to infinite stresses, even at normal frequency. Energy losses however, limit the value considerably.

We might, for instance, in such accident have the line conductors 3 ft. apart and separated by 6 ft. from any wall, and yet upon inspection find that each line was connected through flames to the wall, but that there was no flame between the conductors.

Obviously, if the impedance had been grounded through an arc, high voltages would have resulted, almost independent of the relation between capacity and inductance. The remedy, in that case, would have been a grounded neutral.

Static stresses of generator and transformer windings introduced by accidental ground. A ground might well cause serious breakdowns by the static effect only. Consider, for simplicity's sake, a single-phase system, consisting of a generator, a transformer, and a line.

There is, of course, a certain capacity between primary and secondary of the transformer winding. There is also a certain capacity between the generator winding and the frame, which is the ground.

With the two lines symmetrical and well insulated, there is a balanced capacity against ground, thus the high-potential coils of the transformer are at ground potential; consequently, the low-potential coils and the armature windings are also at ground potential. If now one line becomes grounded, the potential of the coil against the ground is obviously one-half of the line voltage. Consequently, the low potential winding acting as the other plate of the condenser, is also charged to a certain potential, the magnitude of which depends upon the relative capacity of the generator winding to ground and the capacity between the transformer windings. If they are the same, then one-half of the line voltage is divided equally between the primary and secondary of the transformer and the generator winding to ground. If the capacity between trans-

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former coils is twice that of the generator winding against ground, then the generator winding will be subjected to $\frac{2}{3}$ times $\frac{1}{2}$, or $\frac{1}{3}$ of the line potential.

We can readily see from this, when a ground occurs, how the generator might possibly break down, and how in such cases it is important to get at all facts. The remedy is a system with grounded neutral.

How to ground the neutral. Must we ground the neutral perfectly, or can we use resistance or reactance? Without going further into the question, it is evident from the preceding instance that a reactance in the ground connection is not advisable; there are, indeed, several good reasons, but resistance needs some further discussion.

In moderate voltage systems, say up to 15,000 or 30,000 volts, perhaps even higher, resistance is feasible, since under normal operation the stresses are those of a grounded system. When, however, one line is grounded and the current is limited by this resistance, its function as a neutral ceases, and, as far as voltage stresses are concerned, the system might as well not be grounded. It saves, however, a shutdown and permits the systems being rearranged without interruption of service. For transmissions of very high voltage I believe, however, that a good solid ground is best, since any considerable rise might strain the insulation above its safe limit.

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Discussion on "The Telephone Wire Plant" at New York, April 26, 1907.

(Subject to final revision for the Transactions.)

John J. Carty: From the paper it is evident that the telephone wire plant consists of the conducting wires joining points distant from each other, and a large amount of auxiliary apparatus pertaining thereto. This distinguishes the telephone wire plant from that part of the plant which is composed of switchboards, telephones, transmitters, and the various classes of apparatus associated therewith.

The paper does well to call attention to the very great magnitude of the telephone wire plant as compared to the switchboard plant. The switchboard apparatus, all being assembled at the central office, can readily be viewed as a whole, and presents a commanding appearance. Very likely for this reason in the usual discussion of switchboards and switchboard apparatus those factors have been brought into undue prominence as compared with those parts of the plant which have been discussed to-night. The switchboard has too long held the center of the stage, and it is high time that attention has been directed to some of the numerous other features, aside from the switchboard, which are necessary for a complete telephone system.

The telephone wire plant of the city of New York and the suburban territory tributary to it consists in round numbers of one million miles of copper wire. Most of this copper wire is enclosed in lead-covered cables. The superficial area of the lead pipes covering a particular one of these cables amounts to 7.6 acres. The superficial area of the lead pipes covering all of the cables in this system of one million miles of wire amounts to 190 acres. All of this lead pipe is needed to protect from water and moisture the delicate paper-covered wires within, as a puncture in one, of these pipes no larger than a pinhole will admit moisture, which sooner or later causes a fault that produces an interruption of the service of one or of all the circuits within the cable. All of these 190 acres of lead pipe must therefore be maintained free from punctures even as small as that which would be produced by a pin, so that in the manufacture and laying and maintaining of this part of the telephone wire plant very important and serious problems are presented.

A few words concerning the development of this type of lead-covered cable may be of interest as bearing upon the subject under discussion. In the first telephone installations the wires, as a rule, were overhead and composed of iron, following the standard telegraph practice of the time. Soon it became necessary to extend telephone wires across rivers, and here for the first time telephone cables were used, the gutta percha or rubber-covered cables employed by the telegraph companies being imported into the telephone service for the purpose. As the number of wires increased, rubber-covered wires in cables were used to run upon poles and housetops.

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Some use was also made of overhead cables composed of cotton saturated with beeswax and protected with rubber tape and braid. As might be expected in the light of our present knowledge, these cotton and beeswax cables failed. This failure, taken together with the bad experience obtained with paraffin-covered cotton office wires, led to the conclusion that cotton was a bad insulator and for some time, where cables were employed, rubber was the material used.

Owing to the high specific inductive capacity of rubber, the transmission obtained through rubber cables was extremely defective and the cross-talk was almost intolerable.

Experiments were also made with rubber-covered wires at an early date, laid in underground ducts. These wires were unprotected by lead pipe, and besides being open to the before-mentioned objections to the use of rubber cable, were especially subject to decay in many places underground.

All of these experiences led to a search for something better than rubber. Foremost among those who worked upon this problem was Mr. William R. Patterson, whose scientific investigations and remarkable practical skill brought forth a cable consisting of cotton and paraffin, in this respect resembling very much the cotton and beeswax cable which had been the cause of so much disastrous experience. It was difficult to convince anyone that cotton and wax could be a good insulator, but it was shown that perfectly dry cotton was an excellent insulator and that the former failures were due to the fact that, owing to its hygroscopic nature, cotton had absorbed moisture from the atmosphere and in the process of manufacture, and thus had its insulation destroyed. It was demonstrated that if the cotton core of the cable were throughly dried in an oven and then quickly hauled into a lead pipe and sealed up at the ends, that insulation as high as one thousand megohms or more per mile might be obtained, and that this high insulation would persist as long as moisture was kept from the core. The introduction of such a cable involved an entirely new state of the art and required that all those engaged in telephone construction should reform their ideas in the light of the new knowledge. After much agitation and discussion, and after a vigorous campaign of education, the superiority of the fibre cable, properly made and installed and maintained, was demonstrated. From that time the use of rubber cable began to decrease.

After much experience, it was found that the filling of wax might be omitted from the cable and yet the moisture could be kept out. This resulted in dry-core cotton cable, which had the advantage of much lower capacity than the filled cable and was not so much affected by heat as was the cable containing wax. The step from the use of dry cotton to the use of paper was a very important one and accomplished much in the way of economy.

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The underground telephone cable of to-day is composed of copper wires covered with paper, all enclosed in a hermetically sealed lead pipe. This type of cable has persisted so long and seems to answer its purpose so well, that telephone engineers are fairly well content with it, and are no longer agitated by those serious questions which I have just discussed.

The tendency in cable construction and in telephone line construction generally has been to drive rubber insulation out of the field which it formerly dominated. Its use is now restricted to distributing wires, inside wiring, and certain special switchboard wiring. While the use of this rubber insulation has relatively decreased in the absolute amounts used, there has been a tremendous increase in the mileage employed. So important still is the use of this rubber wire that the question of its durability and cheapness is one of very great concern, and I am glad to see that in the paper just read there are some valuable data concerning the durability of rubber wire under certain conditions. Reliable data on this subject are much needed.

The open wires used in the first telephone lines were usually made of iron, and, as a rule, especially when employed in lines of any great length, they gave impaired service. The reasons for this are of course now well understood, but at the time of which I speak not much was known concerning the laws of transmission, nor of the electrical and magnetic properties of iron. There was a long period of groping in the dark. Where long-distance wires—at that time forty or fifty miles was long distance—were used, imperfect results were obtained, and in some cases it seemed that by using larger iron wires matters were made worse. During all of this period of fumbling and groping, there was one engineer with clear vision who perceived that if copper could be obtained with suitable mechanical qualities, it would be an excellent material for telephone lines. He directed his attention to this subject and produced hard-drawn copper wire in suitable form for telephone lines. I refer to Thomas B. Doolittle, who was the first one to use hard-drawn copper wire as the material for telephone lines. Hard-drawn copper wire was thus used by him at an early date at Ansonia, Conn. The results obtained were satisfactory, and, after a number of years had elapsed, a practical demonstration of the value of hard-drawn copper wire for long-distance lines was made by stringing a circuit extending from Boston to New York. The success of this circuit, using hard-drawn copper wire, demonstrated the feasibility of long-distance telephony. Here again the art of stringing wires had to be reformed. Linemen, foremen, engineers, and managers had to be taught how to handle the new material, the factories had to be instructed in its making, and even a new joint had to be perfected. The size of wire to be used had to be determined, and this was found out when the New York-Philadelphia long-distance line was established, upon which wires of various sizes were strung.

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Those which were mechanically weak were eliminated and many valuable data were obtained. Since those times, hard-drawn copper wire has been found to be the only material suitable for long-distance lines. Compound wires of various sorts have been suggested from time to time, but invariably they have been found unsatisfactory for long-distance transmission. Whatever use they have must be for local lines and the precise function of this bimetallic wire in such lines is yet to be generally agreed upon.

While much has already been accomplished in the perfection of the telephone wire plant, much still remains to be done; and to make our record of future achievement as worthy as that which has already been accomplished we must constantly direct our efforts not only along broad and comprehensive lines, but we must also pay strict regard to each and every one of the thousands of small pieces of apparatus, many of which are dealt with in the paper, and all of which go to make up the sum total of the telephone wire plant.

Hammond V. Hayes: The methods of telephone plant development which Mr. Grace has described represent those which we are now employing and which have been employed by the Bell engineers for a number of years past. Practically every city and town in this country has been studied, and all new work is carried out on well-considered lines as formulated by development plans of this character.

The development plan is simply a forecast, what someone, I think Mr. Carty, has called a guess based on scientific or engineering principles, as to what may be expected for the future of the telephone business in each particular locality. So difficult is this forecast of the future, and so inadequate are any rules or formulas, that it has been our custom to employ for this work, as far as has been possible, a group of young men who have gained special training by the varied experience derived from the preparation of plans of this character for cities and towns scattered throughout the country. We find that in many parts of the country the optimism of local men is such as unduly to distort their judgment as to the future size and importance of their own towns; and, occasionally, although rarely, there is such insufficient appreciation of telephone possibilities that there is a tendency to create plants of insufficient size. Even engineers that are detailed for this work have methods of estimating and checking their work which cannot be definitely formulated. In fact, it is their judgment based on wide experience which prevails. I have no doubt that in very many cases as good or better estimates for the future can be made by men of good judgment and good sense without resorting wittingly to the elaborate method such as we describe; I say this but to emphasize the fact that in this as in every other engineering problem it is good judgment based on ample and proper premises which is of importance.

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Mr. Grace has talked and spoken of an "all-cable" plant. I want to emphasize that the all-cable plant as described refers simply to the distribution of lines within a city. All the planning done in every city and town in the country is to arrange the plant so that the distribution of the wires to the sub-stations may be satisfactory and that it may be possible that each sub-station in each town will be capable of talking with every other sub-station in other towns. This placing of lines in cables cannot be applied to the wires used for long-distance circuits to any great extent, for the reasons that the cables tend to cut down the efficiency of service; what must be done is to keep the wire plant of the system not only the best possible for maintenance reasons, but to arrange it so that it is capable of rendering possible communication over the widest possible range of territory.

I am much interested in some of the mechanical features of the plans that Mr. Grace has shown us, and I hope that I may take the liberty of speaking of the cable-box. Mr. Grace has with great modesty said but little about it. This box is his own work; he designed it and perfected it, and I hope that t will be used very generally in the future throughout the United States.

I would like to say one word more about the question of steel and copper wire, following substantially the same thought that was in Mr. Carty's mind. Wire of this character was used some years ago in this country and has been on the market in Europe for many years. I am very glad indeed that the experiments with this wire are being carried out by Mr. Grace. I hope that he will continue the experiments, and will tell us at some later time what his success is and if such a wire offers an additional means of line distribution. I feel, however, that the wire plant is so important a feature of the telephone system that it would be well to go slowly and consider a material of this character as an experiment until such time as it has been more thoroughly tried out.

G. M. Yorke: The system described by Mr. Grace contains a minimum amount of open wire. As Mr. Hayes has said, this system is mainly used for connecting the subscribers' stations with the nearest central office. This portion of the plant has to be made compact and sightly. But a large percentage of its use is merely for communications between stations only a very few miles apart. Now, when we consider that other very important portion of the telephone plant, used for connecting central offices together many miles apart, hundreds of miles apart, we see that such an extensive use of cable is quite impossible. The reason for this is that cable circuits have always been very inefficient in transmitting speech. This inefficiency still exists in spite of the improvements in cable manufacture that have been touched upon and also in spite of other general improvements in the art. As an example of the

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inefficiency of cable circuits, take the type of circuit used for the longest distances in this country. These circuits are about fifty times as efficient as the form of cable circuit described by Mr. Grace, and used so largely for subscribers' lines. In other words, one of the regular lines from New York to Chicago talks as well in volume and in quality as a cable circuit only twenty miles long of the sort described by Mr. Grace. A further point is that if we connect only ten miles of such cable to this long open wire circuit, it is necessary, in order to keep the transmission efficiency at the same point of loudness and quality, practically to double the weight of copper in the long line circuit. Of course this is an extreme illustration. In view of this relative inefficiency of cable circuits, we are not going to speak right away of an all-cable long-distance plant. It is necessary to bring the open wires as near to the center of the terminal cities as is practicable and to keep all cable out of intermediate cities if we can. This becomes more and more necessary in view of the increasing amount of cable that it is necessary to use in subscribers' lines. I simply want to point out that the open wire is not to be abandoned just because it is unsightly. We are going to keep it if we are going to keep long-distance telephone service.

F. L. Gilman: As has been said several times, a material advance has been made in the art of cable manufacture, and the present paper-insulated cable has been used in its present form for a good while with satisfaction. One great effort in recent years has been in the direction of getting more wires into a given amount of space without increasing too much those electrical characteristics of the cable which are harmful to transmission, and without using sizes of wire that cannot be handled easily.

Mr. Grace has spoken of the braided rubber-covered wire used between the cable terminals and the subscribers' stations. Perhaps if I outline briefly the conditions which obtain, the problem of this rubber-covered wire will be realized more clearly. In telephone lines there is constantly a difference of potential existing between the two sides of the line and between one side of the line and ground; and throughout its entire length, in the kind of distribution of which Mr. Grace has been speaking, the line is composed of twisted wire. This is true of the rubber-covered wire as well as of the rest of line. The two wires are twisted together to keep outside disturbances from affecting the telephone transmission. Furthermore, the resistance of the part of the circuit including the rubber-covered wire has certain limitations. Then again, as can be seen from the pictures, this part of the plant runs anywhere and everywhere; it is on walls and fences; it is generally outdoors where it is exposed to sleet and rain; in the summer-time it is subjected to excessive heat, and in the winter-time to extreme cold. In other words, this wire is everywhere in the system and in nearly every telephone line in the large cities.

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Now, if the wire is not in first class condition and has not first-class insulation there are a number of different troubles that exist. In the first place, there is a waste of current and the possibility of electrolysis. Then there is sensitive apparatus in the central office which will be affected. More important than these is the transmission which is also in jeopardy. If there is a leak on one wire of the pair, the line will be noisy; or if there is a leak between the two wires of a pair, reduced transmission will result because of the short-circuit. Another reason for first-class insulation is the fact that this braided rubber-covered wire is fairly expensive to start with, and the running of it is also expensive, so the life has to be long in order to make such construction economical. Furthermore, because of the moving of subscribers, this wire may have to stand taking down and putting up again.

What I want to bring out clearly is the fact that it is requisite that the wire used for this purpose shall be of first-class quality and maintain its insulation. Of course we are more or less familiar with braided rubber-covered wire, but perhaps we have not all realized just what the vital point is. The rubber compound itself will not last unless it is properly protected. The usual method of protecting the braid is a cotton braid, but that will not stand the heat and rain of summer unless it is properly protected, so the whole gist of the matter is the protection of the braid—some protection that will not run off in summer and will not crack in winter.

Kempster B. Miller: I wish that the Institute might have more telephone papers of this kind, wherein plants in different parts of the country are described not only in general terms but with a considerable amount of detail. Such description of practices in different parts of the country, and a frank discussion of them, are just as necessary and desirable in telephony as in any of the other arts, and I think perhaps more necessary, because they have been less common.

It is often interesting to watch the tendency of growth in the development of any art. From what has been said to-night, it is evident that there is a tendency to decrease gradually the use of bare wire in local telephone plants—I am speaking of the local plant as distinguished from the long-distance plant. There are some who contend that there should be absolutely no bare wire in a local telephone plant, and several plants of considerable magnitude have been constructed in which I understand there is not a foot of bare wire. The practice that Mr. Grace has outlined stops just short of this extreme, and it seems to me that it stops in just the right place. To say that there shall be absolutely no bare wire in the plant, simply for the purpose of being able to boast that there is none, is in the nature of riding a hobby rather than of good engineering.

Another tendency that has been brought out, not only by Mr. Grace but by Mr. Carty and others, is the diminishing use of

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rubber-insulated wire in telephone plants. Not long ago we did put a little rubber wire into almost every cable; that is, at the outer end of the cables. The practice that Mr. Grace describes does away with this in a large measure, certainly on all the small cables. He terminates the paper cable directly in a terminal sealed with an insulating compound so that there is no rubber-covered wire in that part of the plant. This means that the only rubber-covered wire is in the drop wires and in the house wires.

Perhaps after hearing of the beauties of the paper cable as outlined by Mr. Carty, people in other arts than telephony may be so impressed that they will adopt paper cable where it may be dangerous to do so. The paper cable is used in telephony because there is no other form of cable that we know of to take its place. Whatever may be said of paper cable, it is subject to one very serious drawback—any slight puncture of the sheath is liable to put all the wires out of business. While such troubles as these are readily repaired, yet they are very apt to occur. In other systems of communication where the high frequencies of telephony are not employed, it is feasible to use rubber or gutta percha insulated wires, and their reliability is infinitely greater than that of paper-covered wire. For this reason where the cable is difficult of access, as in submarine work, or where reliability is of paramount importance, as in the fire-alarm telegraph, the paper cable has little place.

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THE GROUNDED NEUTRAL, WITH AND WITHOUT SERIES RESISTANCE, IN HIGH-TENSION SYSTEMS

BY PAUL M. LINCOLN

The object of this paper is to raise for discussion the question of grounding the neutral, a question that continually confronts the engineer operating an alternating-current generating, transmitting, or distributing system. The writer wishes to consider this question from the viewpoint of the operating engineer, since it is naturally he who is most interested.

The questions that would arise in the mind of the operating engineer would probably be these:

1. Why should the neutral be grounded? What advantage would be gained, if any? and what disadvantages would be encountered?

2. If a ground is used, shall it be at one point of the system, or several?

3. Shall a resistance be used between the neutral and the ground? and if grounded at several points, shall a resistance be used in each place?

4. If a resistance is used, how much? and what shall be its current-carrying capacity?

5. What character of resistance is best?

Let us begin at the beginning of this list of questions and itemize, so far as possible, the advantages and disadvantages of a grounded neutral. The first part of this discussion will deal with the general question of ground versus no ground. Later in this discussion the modifications introduced into this general question by use of resistances, multiple grounds, etc., will be briefly treated.

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Advantages. *a.* Electromotive force between conductor and ground remains fixed and constant.

b. Prevents abnormal static induction on neighboring circuits.

c. Provides opportunity for using the ground as a working conductor.

d. Makes possible the detection (and immediate removal if desired) of any grounded portion of the system.

e. Insures equality in the condenser current drawn from each phase.

Disadvantages. *f.* One ground disables a part or the whole of the system.

g. A proper ground is difficult to obtain.

Discussing more in detail these points of advantage and disadvantage, we find:

Advantages. *a.* In practically every transmission system the greatest danger of breakdown of insulation exists between line and ground, rather than between lines; it is therefore highly important that the voltage from line to ground be permitted to assume no abnormal or excessive value. The higher the line voltage the greater becomes the importance of this point, since the factor of safety of insulation naturally decreases with increasing line voltage. With the neutral fixed at ground potential, it is impossible to obtain, between any conductor and the ground, more than a certain definite proportion of the maximum line voltage. In a three-phase system—including as it does practically all transmitting and distributing systems—the voltage between the neutral and ground is about 58% of that between conductors. If, therefore, the neutral be connected permanently and solidly to ground, the maximum potential that can develop between the line and ground is about 58% of the voltage between the conductors. With an ungrounded system a ground on one conductor will cause full line potential to develop between the two remaining conductors and ground.

On further analysis it is doubtful if all the advantage apparent at first sight is really obtained, for it can safely be asserted that in the large majority of cases it is not the action of the steady line voltage that causes breakdowns in the insulation of transmitting or distributing systems; the voltage strain necessary to cause breaks in insulation is usually very much higher than the normal voltage applied, even in the case where a system is operating with one conductor grounded. The condition giving rise to trouble is to have superimposed upon

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the normal line voltage a so-called "surge" of such value that when added to the normal strain, their resultant causes sufficient strain on the insulation to break it down. Lightning is the usual cause of surges, although they may be caused by many other things; for instance, by switching, or a partial ground, or a broken conductor, or a heavy short-circuit. Insulation being once broken down, the normal voltage is usually sufficient to maintain an abnormal flow of current through the break. With the neutral grounded, a momentary break in insulation at one point on one conductor gives rise to opportunity for a destructive arc at that point. With the neutral ungrounded, before a destructive arc can take place there must be simultaneous breaks on the insulation of two separate conductors. The use of a resistance between the ground and neutral modifies these conditions, as will be discussed in a later paragraph.

A very material advantage incident to this fixing definitely the maximum potential of conductors above ground is that it allows a much closer adjustment of lightning-arresters than would otherwise obtain; that is, the arresters can be adjusted so that a comparatively small rise above normal potential to ground will discharge across them. In an ungrounded transmission system it is not safe to adjust for a discharge potential materially less than line voltage; otherwise in the event of one conductor becoming grounded, the constant discharge which necessarily occurs over the lightning-arresters between the two good conductors and ground will destroy the arresters within a short time.

b. An advantage incident to keeping the neutral of a transmission system at ground potential is to prevent abnormally large static induction by a transmission line on neighboring circuits. Those who have endeavored to operate a telephone line in proximity to a transmission line will realize the importance of this point. It is evident, without further explanation, that so long as the neutral of a transmission line is at ground potential its static influence on neighboring circuits is practically negligible. If, however, one of the conductors of the line is grounded, the static induction of the remaining two is usually sufficient to prevent the satisfactory use of telephone circuits strung on the same right-of-way. Grounding the neutral will prevent such a condition.

As to electromagnetic induction, it is evident that the grounded

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neutral can have no influence unless the ground is carrying current. In that event, electromagnetic induction on neighboring circuits is increased. This increase is due to the fact that the return circuit through the ground, instead of being in close proximity to the outgoing circuits, thereby neutralizing most of its action, is at a comparatively great distance, making the inducing loop of large area and comparatively great power.

c. In a three-phase transmission system with the neutral grounded both at the generating station and a sub-station, it is perfectly possible to continue the transmission of power with one of the conductors out of commission. In this case, if the phases remain balanced, the ground will carry a current 1.73 times that in each of the two remaining conductors. Furthermore, it is perfectly possible to continue to transmit single-phase power with only one of the three conductors remaining. In fact some transmission plants make a practice of running but a single wire to some customers using single-phase current, and but two of their three conductors to other of their customers using polyphase currents, relying in each case on the ground to act as a return conductor for the normal operating current. Still other plants make use of the ground as a working conductor only in emergency.

It must be counted as a distinct advantage in favor of the system with a grounded neutral that it makes available at any time the use of the ground as a working conductor. This does not mean that the ungrounded system cannot make the ground available, but in the latter case special switching arrangements must be provided, while in the former its action as a working conductor is practically automatic.

The practicability of using the ground as a working conductor is also dependent upon the ground resistance. This is an element that varies largely with geological formations, soil, season, moisture, parallel return circuits, and construction of ground-plate; it is therefore difficult to make any general statement covering this matter. However, there seems to have been no difficulty in using the ground as a conductor for moderate amounts of power at pressures of 20,000 volts and above.

d and *f*. With a grounded neutral, a ground on any conductor will cause a short-circuit. This fact may be regarded as an advantage or a disadvantage, depending upon circumstances, and also upon the point of view of the operator. If it is possible by use of the grounded neutral automatically to cut out the

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damaged conductor, and continue service to the affected part of the system over other lines, the grounded neutral may undoubtedly be regarded as an advantage. If, however, the grounding of the neutral means an interruption of service which could be avoided with an ungrounded neutral, the grounding may be justly regarded as a disadvantage. Protection of service is of great importance to the operator, and he is willing to run very considerable risks in order to give continuous service. That certain portions of his system are temporarily overloaded, or that part of his line conductors are temporarily undergoing an abnormal insulation strain to ground, is of no particular moment, so long as service is being rendered and the abnormal condition does not give rise to further trouble. When considering questions of protection of service, the use of

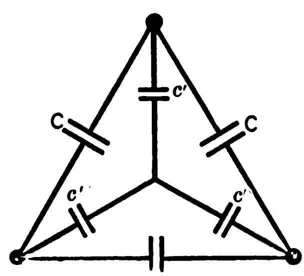

Fig. 1.

resistance in the ground connection is at once involved; the discussion of this phase will be treated in subsequent paragraphs.

e. All alternating-current transmission lines take from the generators a condenser current whose volume depends upon the size, length, and disposition of the transmitting conductors and upon the voltage and frequency supplied to them. These currents may be considered as flowing over two paths, as follows:

I. Through the condensers formed by the conductors as opposite plates, as c in Fig. 1, and

II. Through the condensers formed by considering the conductors as one plate and the ground as the other, as at c', Fig. 1.

The currents flowing through capacity c are evidently independent of any grounded neutral conditions. Those flowing through capacities c', however, depend entirely upon the po-

tential of the neutral with respect to ground. With the neutral at ground potential, the condenser currents through c' are taken equally from each of the three conductors. Assuming an extreme case—one of the three conductors grounded—all the currents through c' are taken from two of the conductors, and further, the total kilovolt-amperes represented by these currents is double what it would be with the neutral at ground potential. A moment's investigation will show this latter point. With the grounded neutral the total kilovolt-amperes, taken through capacities c', may be assumed as proportional to $3\ c'\ E_1^2$, where E_1 is the potential between any conductor and the neutral. Grounding one conductor has the effect of short circuiting one of these condensers and throwing a potential of $E = \sqrt{3}\ E_1$ upon the other two. In the latter case the total kilovolt-amperes taken by condensers c' is $2\ c'\ E^2 = 6\ c'\ E_1^2$.

When the charging current is large compared with the generator capacity, it is probable that such an increase in its volume, as well as taking it largely from two of the three conductors, would cause a serious unbalance in voltage between phases. This seems to be a good, though not controlling, reason for maintaining the neutral at ground potential.

g. A satisfactory ground is very difficult to obtain. The antiquated idea that the ground is of zero resistance, because it is of practically infinite cross-section, has long since been recognized as an error. In case of grounding to a buried plate, most of the resistance of the ground occurs in the immediate neighborhood of the ground-plate, and the ground resistance depends upon the character and condition of the soil in the immediate neighborhood. This is to be expected on account of the fact that it is only in the immediate neighborhood of the ground-plate that the cross-section of the ground, considered as a conductor, is sufficiently restricted to give rise to any appreciable resistance. The conditions other than the character of the soil that make for a low-resistance ground are moisture and the exposure of a large surface of ground-plate: the larger the exposed surface the lower the resistance. It is this reason that makes water-supply systems good grounds.

Even where good engineering practice dictates a resistance in the neutral, the unavoidable resistance in the ground connection is not so valuable as it might be, because of its extreme variability. The difference of the seasons, as well as the drying-out action of any ground current that may flow, will cause large

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variations in ground resistance. However, on high-potential systems the presence of even the maximum amount of resistance that is contingent upon good construction is rarely sufficient to cause trouble.

Modifications Due to Use of Resistance and Multiple Grounds.

If an operating engineer has come to the conclusion that his neutral should be grounded, the next question is, naturally, that concerning the number of places to ground—whether it shall be at his power plant or plants only, or at other points where neutrals can be obtained. The answer to this question usually depends upon the object sought in grounding. If it is the use of the ground as a working conductor, there must naturally be grounds both at the generating and receiving points. On the other hand, if the object is to prevent an abnormal voltage rise on any conductor, due to the grounding of another, then the grounding of the neutral at one point is sufficient and in most cases preferable.

In some methods of connection the problem is still further complicated by the entire absence of an available neutral. In any three-phase system a delta connection of transformer or generator windings gives no opportunity of obtaining a neutral. A delta connection requires the use of a separate autotransformer connected across proper points of the delta, from the winding of which a tap may be brought out for the neutral connection. A three-phase star-connected generating system has of course the neutral at the star connection. If, however, a bank of transformers has both the primary and secondary connected in star, the star connection is not necessarily at the neutral point. In this case the neutral is practically free to move around anywhere within the three-phase triangle; in case of a dead short-circuit on any transformer, the voltage on that particular one disappears and the two remaining transformers assume the whole potential of the line, being then virtually connected in *V*. If, therefore, the star connection of a star-to-star group of transformers be connected to ground, it does not follow that the neutral is grounded; if one side is connected in delta and the other in star, then the star connection can be treated as a fixed point at the center of the three-phase triangle. In a star-to-star group proper conditions can be assured only by connecting the star point on either side to a fixed neutral—such for instance

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as the connection of the star of the transformers to the star point of the generating system. The star point of the generating system being fixed at neutral, this also fixes the transformers.

The question as to how many points of a system shall be grounded is naturally influenced by the above considerations. The final answer, however, must be dictated by considerations which depend upon the reason leading to making any ground connection.

Probably the most important question in connection with this whole matter of grounding the neutral is that as to the use of resistance between the neutral and ground and the amount of resistance that is best. In considering this question the following analysis is pertinent. In any polyphase system, so long as each conductor has the same capacity and ground, the same insulation from ground, and a balanced load, the neutral will remain at ground potential, whether it is connected to ground or not. In other words, so long as conditions on the transmitting or distributing system remain normal there is no occasion for grounding the neutral, as nothing will be accomplished thereby. The object sought in grounding the neutral is to take care, not of normal conditions, but abnormal ones. It is the first thought of the operating engineer to maintain his service, and he therefore installs automatic circuit-breakers and other devices to protect his system in case of an abnormal condition arising. The abnormal conditions that may arise are: 1, short-circuits; 2, open circuits, and 3, grounds.

1. *Short-circuits.* By short-circuits is meant accidental connection in any manner between conductors of opposite polarity. It is evident that under this condition the behavior of automatic devices is in no way influenced by grounding the neutral, so that the consideration of this contingency is not pertinent to this paper.

2. *Open circuits.* In a three-phase line, with the neutral grounded at both generating and receiving stations, the ground will, under normal conditions, carry no current, even though the ground be of zero resistance. If, however, one of the conductors should break, the ground immediately begins to carry current. If induction or synchronous motors are being used at the receiving end, the hree-phase relation will be approximately maintained, the degree of approximation depending upon the ground resistance and upon the relative motor load to non-motor load. If the neutral is grounded at one point only, an open

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circuit in one conductor will have an effect no different from that which would take place if the neutral were not grounded, except that the distribution of charging current between conductors will be somewhat disturbed and more or less of this current would pass through the ground connection.

3. *Grounds.* A ground is the most frequent abnormal condition that is encountered, and also is the one most affected by grounding the neutral. With the neutral connected direct to ground, another ground on any conductor means a short-circuit; the action of automatic circuit-breakers will then take place accordingly. The amount of current that will flow through such a short-circuit can be limited by inserting resistance, and practically the only object of resistance is to cause such a limitation of current.

The flow of excessive currents, such as would take place were there no resistance, is detrimental for several reasons. It throws an unnecessarily great strain upon the circuit-breakers which are called upon to interrupt the current. The large current flow which takes place may cause a phase distortion and drop of voltage which may, in turn, be sufficient to cause synchronous apparatus on the line to drop out of step. Almost invariably an arc takes place at the point of grounding of conductors, and an excessive current will cause excessive destruction at this point. A dead short-circuit on any system causes a heavy shock due to the tremendous currents, and a consequent tendency to distort the windings of any synchronous apparatus connected to the system.

All of these objections can be overcome to a greater or less degree by resistance in the neutral. Increased neutral resistance, however, while it limits the current flow through a grounded conductor and overcomes the above objections, can do so only by allowing an increase in the potential of the two good conductors above ground while the current flows. If the object in grounding is to prevent such an abnormal rise, the inserting of resistance tends to defeat that purpose. The choice of the proper resistance becomes a question of compromise between the disadvantages of going to either extreme. There seem to be good reasons for adopting a ground resistance which will lie between the following limits: on the one hand, large enough to prevent a severe shock to the system; or the voltage on the affected phase dropping to a point where the synchronous apparatus will drop out of step. This consideration will dictate

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a resistance that will not allow more than, say, three times full-load current at the most to flow through the armatures of the generators supplying the circuits. On the other hand, the resistance must be small enough to permit sufficient current to flow to trip the heaviest circuit-breaker on the system.

In all alternating-current circuits there is present a condition equivalent to a neutral grounded through a certain amount of resistance, in that static capacity exists between any conductor and ground. The longer the line and the higher the voltage and frequency, the lower the resistance in the equivalent circuit having a resistance in grounding connection. The effect of a grounded neutral, either with or without resistance, is, in case a conductor becomes grounded, to pass a current of greater or less volume through the affected conductor and into the ground. The effect of the static capacity of conductors to ground is exactly the same, the difference being that no current passes into the ground at the generating station, and that the phase relation of the current through the capacity to the electromotive force producing it are not the same in both cases. The static capacity of an overhead conductor to ground is, with ordinary line construction, from 30 to 50 per cent., greater than that between conductors. Assuming a fault that makes the affected conductor of the same potential as the ground, the affected conductor will take roughly 50 percentage more charging current than the unaffected ones. It may be noted also that the total kilovolt-amperes of charging current in all conductors will be increased about 33 per cent. Where the normal charging current amounts to a considerable percentage of the total generating capacity, as it will in long, high-voltage, high-frequency lines, it will be seen that the condenser effect has the same action as a moderately-low ground resistance.

If a ground resistance be used, the question of its current-carrying capacity is an important one. Since current is drawn through the ground resistance only during emergencies, its capacity should be chosen to meet the maximum that any emergency can throw upon it. Usually the time during which current will flow is limited to the time required to trip a circuit-breaker, probably not more than a few seconds at most. The quantity of current that will flow as a maximum is also fixed as that which is required to trip out the heaviest set circuit-breaker. The question of current carrying capacity is therefore one which depends upon the character and setting of the safety devices used.

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As to the character of resistance, permanency is the most essential. Considerable latitude is allowable in the amount of resistance, but that latitude does allow variations of many hundred per cent., such as past experience has shown is apt to take place with graphite mixtures of similar structures. A metallic resistance is satisfactory but has the objection of being expensive and bulky when the voltages involved are high. This problem has not yet been satisfactorily solved, but it seems probable that where high resistances are demanded—200 ohms or more—some form of non-metallic resistance will be found of sufficiently permanent character to be satisfactory.

In the preceding matter the writer has endeavored to present some of the considerations to be taken into account when this question of grounding the neutral arises. There are so many variables connected with this matter that it is impossible to draw any conclusion that will be general in its nature. The proper action to be taken depends upon the specific conditions surrounding each individual case.

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EXPERIENCE WITH A GROUNDED NEUTRAL ON THE HIGH-TENSION SYSTEM OF THE INTERBOROUGH RAPID TRANSIT COMPANY

BY GEORGE I. RHODES

The chief circumstance which led to the grounding of the neutral of the Interborough Rapid Transit Company's high-tension system was the serious nature of cable burn-outs. As a rule the detectors gave indication of a ground on one leg of the system from five to thirty minutes before the circuit-breaker opened, but on account of the large number of feeders connected it was practically impossible to isolate the damaged feeder before the short-circuit occurred. In a total of twelve operating burn-outs, the grounded cable was located butt wice in time to prevent trouble.

During the period between the first grounding of the cable and the final short-circuit, the system was operating under abnormal potential conditions, the two ungrounded phases operating at full delta potential of 11,000 volts above the ground. Undoubtedly the potential between phases was raised to a certain extent by the increased charging current due to unbalanced potential conditions. The presence of abnormal potentials during this period of ground was evidenced by static discharges in the power and sub-stations that could hardly be accounted for by the operation of two legs at 11,000 volts above the ground potential.

The charging current which flowed to ground through the fault before the short-circuit between phases was large enough seriously to injure the insulation of all three conductors, so that when the burn-out occurred it was so severe that the oil-switches usually opened with considerable violence. Surges

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were started which at times caused other burn-outs to follow, in one instance causing a very disastrous shutdown.* The cable itself was always considerably burned, all three legs being grounded and usually burned off. At times the conductors were blown apart several inches. With the faults in this condition, it was quite impossible to locate them by the bridge method, and it was necessary to open a great many manholes before locating the trouble.

In view of the fact that one phase of a cable almost invariably grounded some time before short circuiting, it was decided to ground the neutral through a resistance of proper magnitude to allow sufficient current to flow to remove the grounded feeder without affecting the system in any other way. It is obvious that with only two feeders to a sub-station, a ground on one of them will open the circuit-breakers of both, and that the certainty of continuous operation of the sub-station increases with the number of feeders.

The scheme of grounding the neutral as originally proposed was as follows: the neutral point of each generator was connected to a common or neutral bus-bar through a disconnecting switch and a current transformer. The transformer operated a relay on the main switch of the generator. The neutral bus-bar was grounded through a resistance of about six ohms in each power station, making about three ohms' resistance between the neutral and ground of the combined system. In case of a ground, the maximum possible current was 1000 amperes per rheostat, all of which was generated by the grounded generator. The relays on the feeder-switches were set to operate instantaneously at 300 amperes, and the generator relays at about 900 amperes after five seconds. Under these conditions it was to be expected that a ground on a cable would instantly remove it from service before any other disturbance could result.

The neutral rheostats were of the iron grid type having a resistance of about six ohms and a reactance at 25 cycles of about 0.3 ohms. They were made up in sixteen series sections, each insulated from the others and from the ground by porcelain insulators. Each section was made up of six series groups of cast-iron grids connected two parallel and twelve series per group. Each grid was made up of ten bars 0.25 in. by 0.75 in.

*See paper on "High Power Surges in Electric Distribution Systems of Great Magnitude," by C. P. Steinmetz, Transactions A. I. E. E., 1905, also discussion on same.

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by 6 in., and two bars 0.25 in. by 0.75 in. by 4 in. A number of extra grids were used to adjust the resistance to the required value. The rheostat will carry 1000 amperes for two minutes, a capacity far in excess of anything that would be required in service.

With the scheme as above outlined, very serious trouble was encountered from the triple-frequency cross-currents in the neutral connections. These neutral currents fluctuated very rapidly from nothing to one-half full-load current per generator.

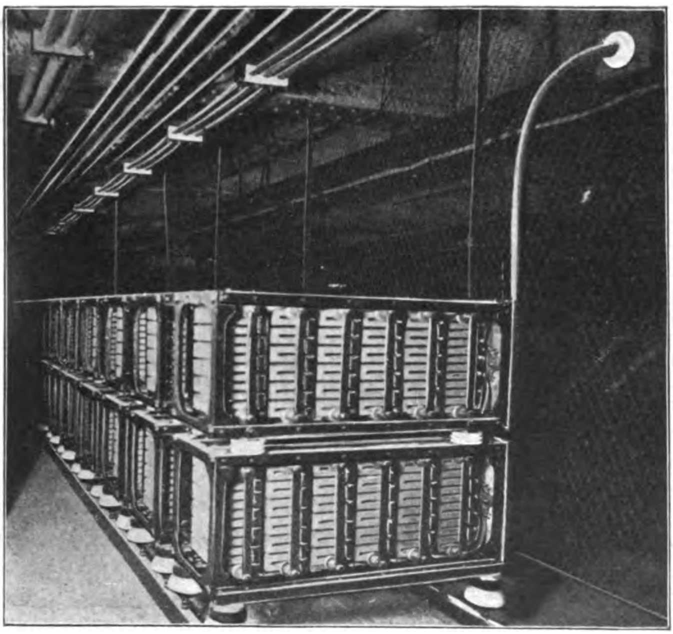

FIG 1

Upon synchronizing there was a very large rush of current in the neutral, so large in fact that with four generators running it was very difficult to synchronize a fifth with its neutral grounded.* These cross-currents had such serious effects on the operation of the system that the scheme of grounding the neutral was delayed for a time to allow making some experiments.

An oscillographic study of the neutral currents was made

* "Experience with a Grounded Neutral on a High Tension Plant," C. W. Ricker, *Electric Journal*, September, 1906.

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and has been described fully.* The records proved without a doubt that the currents were caused by irregularities in the angular velocity of the prime movers and unequal excitations of the generators. It was found that the insertion of resistance in the neutral connections of the generators would reduce the currents to a safe value. This, however, was undesirable on account of the variable resistance in the ground circuit, depending on the number of generators in operation. Furthermore, resistances of sufficient magnitude and capacity would have occupied too much space to be used in these power stations.

It was finally decided that full protection could be obtained by connecting but one line generator at a time to the neutral bus-bar in each power station. The transformers in the neutral connections were also disconnected from the relays on the main generator switch. Even with but one generator grounded in each power station, the interchange of current through the

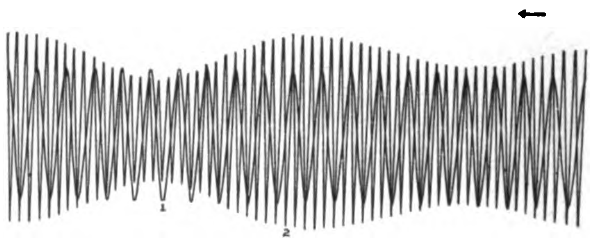

FIG. 2.

neutral rheostats, and the tie-line between the stations, is at times large enough to make it undesirable to open the neutral disconnecting-switch of a live generator.

The Interborough Rapid Transit Company's system was operated for about three and one-half years without a grounded neutral, in which time about 160 miles of cable was operated for three years and 340 miles for one-half year. Since grounding the neutral, the system has been in operation for two years with about 340 miles of cable.

Previously to grounding the neutral, there were twelve distinct operating burn-outs, and since then there have been sixteen. It appears from this fact, that grounding the neutral has had no material effect on the number of burn-outs. This is as was expected.

* "Neutral Currents of a Three-Phase Grounded System," *Electric Journal*, July, 1907.

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Of the twelve burn-outs occurring previously to the grounding of the system, four shut down the power station; one other shut down two sub-stations; and four more shut down one sub-station. Of the other three which did not shut down the sub-station, two were isolated in time to prevent a short-circuit. In all of these cases, there were five or six cables to a sub-station. During most this period only the Seventy-fourth Street power station was in operation, so that there were no tie-line troubles.

Of the sixteen burn-outs that have occurred since grounding the neutral, not one has caused a shutdown of either power station; eight have shut down the sub-station fed by the cable, two have caused one other feeder to open, and six have caused no disturbance other than the opening of the switches of the feeder in trouble. In three of the cases in which the sub-station was shut down, the tie-line between the power stations opened,

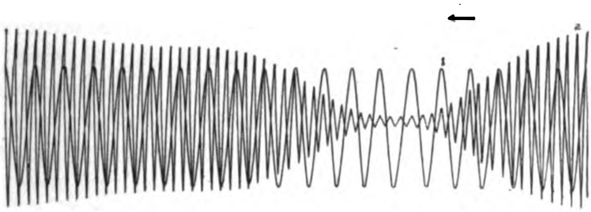

FIG. 3.

but without disturbing the operation of either. Of the eight burn-outs which shut down the sub-station, three were stations having three feeders each, one having four feeders, two having five feeders, and two having six feeders. Of the other eight burn-outs which did not shut down the sub-station, two were sub-stations having three feeders each, two having four feeders, two having five feeders, one having six feeders, and one having seven feeders.

Previously to the grounding of the neutral, the switches operated with explosive violence on the short circuiting of a cable, at times throwing oil and burning the contacts. Under present operating conditions, however, the switches always open very quietly, so quietly in most cases that it was necessary to install a tell-tale to indicate when there had been abnormal current through the neutral rheostats.

Before grounding the system, in all burn-outs the cable was

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so badly injured that it was impossible to make any bridge test, and it was necessary to open a great many manholes before locating the trouble. Of the sixteen burn-outs that have occurred since the grounding of the neutral, fourteen of them were in such condition that the fault could be easily located by the Murray loop method. In most of these cases but one leg was grounded. In the two cases where all three legs were grounded, making the bridge test impossible, the burn-out was the result of very severe mechanical injury. Locations of the fault are always made to within a duct length, even on the longest cables of more than 45,000 ft. The saving in time effected by this accurate predetermination of the trouble by the bridge method is an important factor in the time necessary to restore a sub-station to normal conditions of operation.

It is probable that something would be gained by increasing the resistance between the neutral and ground. When the scheme was first contemplated, it was planned to ground the neutral through six ohms, there being at that time but one power station. Now with two stations in parallel the effective grounding is through but three ohms, making the possible ground current twice that originally planned for. There is no doubt but that with the resistance as first decided upon there would have been fewer sub-station shutdowns.

From the above data, it is seen that grounding the neutral of this system through a series resistance has been quite successful. It has greatly reduced the disturbance from cable burn-outs and the time necessary to restore an injured cable to service.

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A paper presented at the 221st meeting of the American Institute of Electrical Engineers, New York, October 11, 1907.

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THE GROUNDED NEUTRAL

BY F. G. CLARK.

During the consideration of the design of one high-tension installation, the question of grounding the neutral was investigated, and resulted in a decision to ground the neutral points of the generators through a limiting resistance. It was my privilege to contribute to that design and to recommend that this resistance be omitted. The reasons for grounding, the reasons for and against the resistance, and facts relatively to operation covering a period of over two years may therefore be of interest in connection with this discussion.

The installation comprises a power station centrally located for the ultimate conditions prescribed, but unfavorable to the preliminary electrification of a steam railroad requiring seven sub-stations, and undergound and overhead transmission of three-phase current at 11,000 volts and 25 cycles. Fig. 1 will give an idea of the present and ultimate conditions. The future circuits from the power station will be underground cables. There are now five 250,000-cir. mils, three-phase circuits leading from the station undergound to No. 1 cable house. From there the feeders are aerial to sub-station No. 3. This will be seen to be the distributing point for the present installation. Two aerial circuits lead to sub-station No. 5. At cable-house No. 2 the circuits are submarine, and again at cable-house No. 3 submarine cables are used from the north end of the draw to the sub-station.

The feeders leading east and west from sub-station No. 3 are underground. Three circuits lead to sub-station No. 2, and from there two circuits lead to sub-station No. 1. Three circuits lead to sub-station No. 4 and are overhead from cable-house

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No. 4. From No. 4 sub-station one circuit leads direct to sub-station No. 6 and another to portable station No. 1, and from there to No. 6. At portable station No. 1 a three-phase No. 2 conductor branch leads to sub-station No. 7. One circuit leads from sub-station No. 4 to portable station No. 2, and from there a single-phase No. 1 conductor circuit leads to transformer station No. 1. A typical location of this system and length of feeders is shown in Fig. 2.

The protective features are low-equivalent lightning-arresters, inverse time-element relays on circuit-breakers, a peculiar method of operating exciters, and the grounded neutral. A voltage

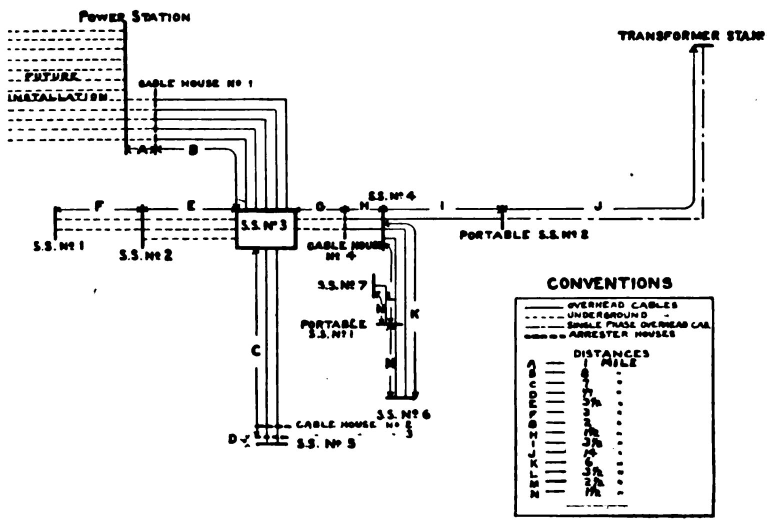

Fig. 1.

regulator has lately been installed and has a bearing on the situation.

The lightning-arresters are used in connection with choke-coils at the ends of all overhead feeders. They tend to protect the undergound feeders, the station apparatus, and, to a certain extent, the aerial transmission lines from the effects of lightning and from static strains due to switching, grounds, or short-circuits. The arresters are set to discharge at 8500 volts. The pressure between the ground and two conductors of the 11,000-volt, three-phase system, with one conductor grounded, is 11,000 volts when the neutral is not grounded; it is 6380 volts when the neutral is dead grounded; it is between 6380 volts and 11,000

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volts with resistance in the neutral conductor. The locations of the lightning-arresters are shown in Fig. 2.

The inverse time-element relays afford protection against overloads, and are used in connection with the oil circuit-breakers on all feeders. The speed in opening the circuit-breaker varies with the increase of current in the circuit controlled.

The relays at the power station ends of the feeders are set to allow a maximum of current to flow for a period of five seconds before they actuate the control circuits to open the circuit-breakers. This is just above the amount of current allowed as a maximum per feeder. The relays at the nearest sub-station are set to open the circuit-breakers on feeders to more remote

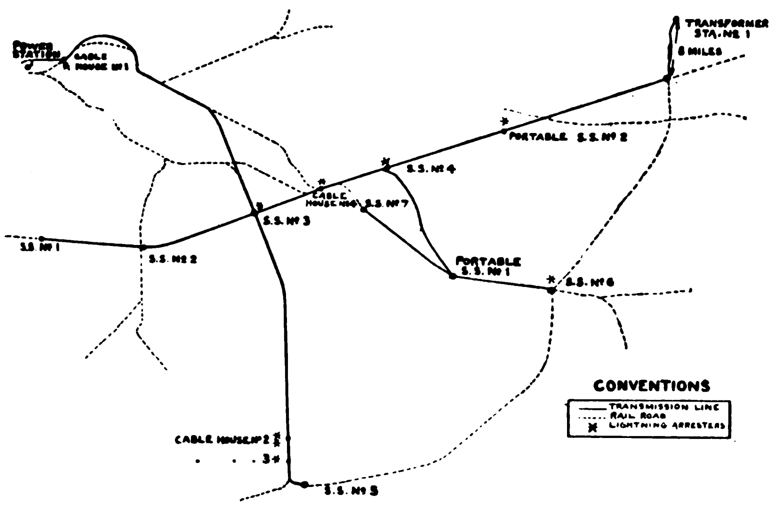

FIG. 2.

sub-stations in four seconds for the same current. The relays in the sub-station next in progression are set for three seconds with the same current, and so on. The relays are connected with series transformers, one on each leg of the circuit controlled, to open the circuit in the event of one leg grounding.

The excitation of the generators depends upon induction motor-generators, with no steam exciter, or battery reinforcement, although both are available for starting up in case of an interruption. The induction motors are supplied from the main generators through transformers and have about 2.5% slip. The output of the exciters depends upon the power-factor, which decreases with the voltage. The excitation automatically ceases whenever the bus-bar voltage goes below 5,000.

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A voltage regulator tends automatically to increase or decrease the generator excitation as its voltage lowers or rises. The effect of this is to increase the intensity of the accidental overload and therefore hasten the automatic interruption. This is a radical change from the usual practice of holding up the exciter voltage under all conditions. It means a few more power station interruptions, but less damage when short-circuits occur, and less time lost in sub-stations.

The foregoing explanation of the protective features of this installation may appear to be irrelevant to a discussion of the grounded neutral, though it has a bearing which should not be overlooked. The neutral point of each generator is led to a bus-bar through a fourth pole of the generator circuit-breaker. The neutral bus-bar is connected to one end of a cast grid resistance suitably insulated. The other end of the resistance is connected to a ground-plate located in earth kept moist with salt water. There is 6.7 ohms resistance, or sufficient to allow 1000 amperes in the neutral circuit in the event of a ground. A current of 1000 amperes will raise the temperature of the resistance approximately 1000° fahr. in one minute. An ammeter on the switchboard indicates the amount of current in the neutral connection. A pilot lamp lights whenever 50 amperes or more flows through the resistance. This lamp remains lighted until an auxiliary circuit is opened, and has been instrumental in determining the number of short-circuits that were also grounds.

The grounded neutral affords protection against rises in potential and high-frequency oscillations due to grounds. An accidental ground will establish a power circuit supposedly sufficient in all cases automatically to open the circuit-breaker. Were the neutral not grounded, the accidental ground would allow the charging current to be discharged through it, tending to burn the insulation and cause a short-circuit in the case of an underground cable, or burn off the conductor in the case of an aerial line. The electrostatic change would also tend to cause oscillations in the case of underground cables and possible breakdowns at various points of the system. This has occurred during the operation of several high-tension systems.

Grounding the neutral has the disadvantage of increasing the number of short-circuits, and consequently the interruptions of service. These short-circuits are dangerous to power-station apparatus, as they may cause breakdowns involving greater expense and loss of service than the possible resonance troubles.

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There are conditions peculiar to each installation which have a bearing on this question, and these conditions determine the necessity of a resistance in the neutral circuit, the amount of resistance to be used, whether more than one generator should be grounded.

In systems where synchronous converters have low synchronizing power, the voltage drop due to grounds will cause the converters to drop out, and a limiting resistance must be placed in the grounded neutral. In other systems the generator coils are insufficiently braced, and resistance in the neutral is a preventive for generator breakdowns. In stations where the generators are driven by slow-speed reciprocating engines the neutral points cannot be connected to a common bus-bar on account of cross-currents. A resistance would be required for each generator or that one generator be run with its neutral grounded.

A consideration of these facts led to a decision to use a resistance of 6.7 ohms in the power station of the installation described. It was anticipated that this resistance would allow sufficient current to flow through any ground which might occur to clear the system of that ground, and that grounds on two legs or short-circuits would be cleared by the inverse time-element relays, or, if very close to the power station, by an interruption of service due to the "killing" of excitation. The events of operation indicate that the neutral ground is essential and that the other protective features perform their functions suitably.

Conditions obtain, however, which mitigate against the proper operation of this protective feature. One instance will serve to illustrate this point. A wire-rigged sloop which had been anchored near the cable-house No. 2 draw (Fig. 1) drifted out of the channel until a stay-line connected with one leg of the transmission circuit, causing a ground. The ground held for about three minutes, when the boat shifted and another part of the rigging connected with a second leg, causing a short-circuit which opened the circuit-breaker. The current in the ground circuit was approximately 400 amperes, which was not sufficient to open any of the circuit-breakers between the ground and the power station. It was enough, however, to burn off an anchor chain and several of the wire stays on the boat, and to raise the temperature of the neutral resistance to that of a bright-red heat.

When the ground occurred, the neutral point rose from 0 to about 2700 volts, and the two ungrounded legs were approxi-

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mately 9000 volts to ground. The electrostatic condition very nearly approached that which would obtain in an ungrounded system. The lightning-arresters being set at 8500 volts, began to discharge, and oscillations were a possibility.

The inductive drop and the resistance of the ground, added to the set resistance of 6.7 ohms, were sufficient to limit the current to 400 amperes. With the 6.7-ohm resistance out, the current would have been above 650 amperes, or sufficient to have opened the nearest controlling circuit-breaker in less than one second. The inductive drop was about 1000 volts and the resistance through the ground sufficient to divert the current to the numerous telephone lines as paths of least resistance. The fact that telephone troubles are not coincident with grounds of short duration would seem to indicate that induction is not an important factor in this particular case. There have been no indications of trouble in telephone or telegraph lines due to induced potential.

Some action must be taken to prevent this ground current from causing trouble. The grounded neutral is a preventer of electrostatic troubles and therefore shoud be retained. The resistance is a positive detriment to receiving the full benefit of this effect. It should, therefore, be omitted whenever the local conditions will permit. In the case described this can be done without perceptibly increasing the hazard to apparatus. This would enable the relays to clear any of the grounds that have occurred within five seconds.

A transmission line may be so long that its total drop and the resistance of the ground will produce a condition analagous to that described. Such a case would require special treatment, as, for example, providing a low-resistance neutral conductor leading to a point safely within the area normally protected by the neutral ground at the station, and equipping the feeders to points beyond, so that they may be open by a relay. The relay could be actuated by a small current flowing in this extension of the neutral, and in phase with current flowing in one leg of the feeder. Such a condition does not obtain on the system described and we can therefore be reasonably assured that in removing the neutral resistance we will have removed the cause of trouble incident to the grounded neutral.

During two years' operation there have been over 70 short-circuits. About 25 of these have caused sub-station interruptions, and 6 have been close enough to cause power-station

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interruptions. About one-half of these short-circuits showed a ground connnection. There have been 10 grounds, of which the neutral ground cleared 8. One held for four minutes and one for three minutes, both developing into two-wire short-circuits.

It is quite probable that in a system operating with underground cables only, there would be no outside disturbances in connection with sustained grounds. The lead sheaths which are generally bonded together in manholes would provide the path of least resistance for the ground circuit. The ultimate installation will require undergound cables, and except for the greater power effects, and greater charging current, will alter the present situation but little.

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A paper to be presented at the 222d Meeting of the American Institute of Electrical Engineers, New York, November 8, 1907.

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COMPARATIVE PERFORMANCE OF STEAM AND ELECTRIC LOCOMOTIVES

BY ALBERT H. ARMSTRONG

So many excellent papers bearing upon the subject of steam road electrification have recently been presented to the engineering public that the writer hesitates to add to their number. In the hope, however, of offering a somewhat clearer insight into the fundamental reasons underlying the electrification movement, this paper is written from the standpoint of a technical comparison of the performance of steam and electric locomotives.

Among the many electrification projects now in course of construction, nearly all were inspired by such motives as cleanliness, smokelessness, convenience, etc., but few indeed have been considered strictly from the standpoint of direct financial benefits to be obtained. The improvements in and around New York City terminals, the various tunnel projects such as the early Baltimore and Ohio installation, and later the Sarnia, Detroit River, and Cascade Tunnel projects—all are examples of steam road electrification in which there were distinct reasons for displacing steam as a motive power, but there are other sections of our steam lines where these same reasons do not apply with equal force, and benefits of a more far-reaching nature must be made evident before such electiifications can be considered as necessary or desirable. It is concerning these other sections of steam lines demanding other reasons for electrification that this paper is written, and the best means to be employed in getting a thorough grasp on the subject seems to lie in an investigation into the comparative inherent qualities of steam and electric locomotives.

Before considering the electric locomotive, much the simpler of the two, it is advisable to deteımine the general characteristics

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and limitations of the steam locomotive viewed from the standpoint of the electrical engineer, in order that the scope of the problem may be thoroughly understood and the lines of contrast be sharply drawn.

This preliminary study of the steam locomotive is made necessary by the fact that railroad practice to-day is essentially *steam* railroad practice and is hedged about by practices and methods of operation demanded by the use of the steam locomotive as a type of motive power. Viewed in the light of greatest benefits to be secured, the coming of the electric locomotive is not due to petty economies affected in coal consumption and cost of locomotive repairs; indeed, with coal as a common source of power, little gain in efficiency is secured through burning the same grade of fuel under stationary boilers over the excellent results obtained with the highly perfected modern compound locomotive. As will be discussed later, there exist certain fundamental relations between the cost of producing a horse power at the drivers of a steam locomotive burning its fuel on the structure, and a horse power at the drivers of an electric locomotive deriving its energy from a distant stationary power house via a distribution system. The use of water power, or of a cheaper grade of fuel than can be burned on a steam locomotive, will in many cases afford a means of reducing the fuel cost well below the present cost of high-grade coal required for successful locomotive operation; but in general the fuel item reduction does not in itself offer a sufficient saving to pay an adequate return on the large investment required for electrification.

It is necessary, therefore, to look for more far-reaching benefits, and, not considering the reasons governing the introduction of the electric locomotives at terminals and in tunnels, we find in a comparison of the characteristics of the steam and electric locomotives a contrast so marked that it shows not only the superiority of the electric locomotive for general railway conditions but it also suggests changes of a fundamental nature in present methods of operation now necessary with steam locomotives. And these benefits to be secured occur not only in the operation of passenger trains, but are felt to an even greater degree in the haulage of the heaviest freight trains, a field supposedly the exclusive domain of the steam locomotive.

The steam locomotive has two component parts, the boiler and the engine, both of which have their own individual characteristics; and the relation between the two is generally deter-

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mined by the character of the service for which the locomotive is desired.

The steam locomotive boiler is universally of the fire-tube type, though experiments with water-tube boilers point to certain possibilities in this direction. Owing to the restrictions of width and length available, the locomotive boiler must of necessity be worked to its limits in order to generate the greatest amount of steam possible. It is not the purpose of this paper, nor is it necessary, to go into a detailed discussion of the proper relation between grate area and heating surface, fire-box construction, length of tubes, diameter, etc., all constituting improvements in locomotive design directed to the better evaporation of water per pound of coal burned and the greater capacity of a boiler built within the space allowed. It suffices to use values of water evaporation, coal consumption and general boiler performance as obtained in experimental tests, and modify these " best performance " values by the knowledge of conditions obtaining in practical service.

The locomotive engine is distinct from the locomotive boiler, and when supplied with unlimited steam at constant pressure it has its own characteristics and maximum output both in tractive effort and horse power. Engines are of two general types, simple and compound, the latter being introduced in order to affect a saving in the large steam consumption inherent to non-condensing engine operation. The success of the compound locomotive is very much a matter of discussion among railroad men, but it seems to have found a permanent foothold upon easy-grade lines although its use is still open to serious question upon the heavy mountain-grade divisions. In general, the electric locomotive must compete with the compound steam locomotive on level divisions and the simple engine on heavy grade divisions, although the Mallet compound has lately been introduced with some success in this latter class of work.

The general shape of the steam locomotive characteristic is given in Fig. 1, which shows the relation between the speed and tractive effort of a simple consolidation locomotive designed for heavy freight service. Owing to clearances it is seldom that a locomotive can work at more than 90 per cent. of the theoretical full stroke, and hence the maximum tractive effort at starting with lever in the corner will not be much greater than 88 per cent. of the theoretical tractive effort available with gauge pressure in the cylinders. An inspection of Fig. 1 shows that

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the steam locomotive is limited as to maximum tractive effort by its engine design, and limited as to the speed at which this tractive effort is available by the capacity of the boiler to supply steam. Thus, assuming that the locomotive will give 88 per cent. of its theoretical tractive effort when starting, it is capable of providing but 80 per cent. tractive effort at a speed of 10.6 miles per hour (with the constants of the particular locomotive

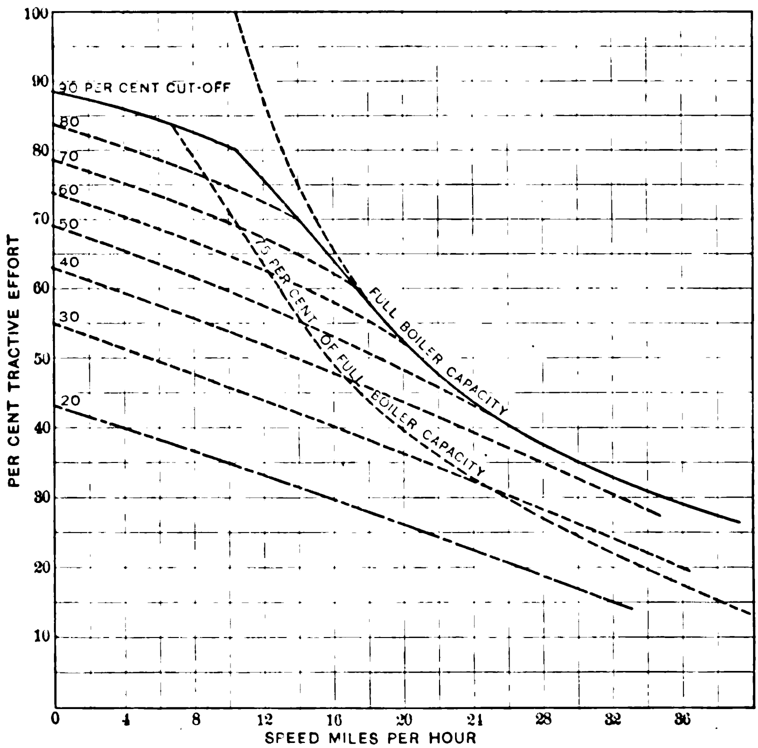

FIG. 1.—Typical steam locomotive characteristic (simple)

chosen for illustration) at which the boiler is giving its full output. Hence higher speeds can only be reached with a lesser cut off and a consequent reduction in mean effective pressure and tractive effort. Locomotive engines are generally designed to give their maximum tractive effort at 90 per cent. theoretical cut-off at a point corresponding to a coefficient of adhesion of approximately 22 per cent. of the weight upon the drivers; that is, at about slipping point of steam locomotives with good rail

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conditions. It is immediately evident therefore, that the tonnage rating of the locomotive on ruling grade must be so proportioned that the maximum tractive effort called for will be less than the available tractive effort of the locomotive in order to provide a small percentage, say 10 or 15 per cent., for possible starting under maximum grade and load conditions. In other words, as the steam locomotive is designed so that the maximum tractive effort is delivered at a point not greater than 22 per cent. of the weight upon the drivers, it is not possible to take advantage of possible abnormally good rail conditions (either natural or made abnormal by the use of sand) as the engine itself will fail to deliver any excess tractive effort thus made available with increased coefficient of adhesion.

On the other hand, the tractive effort of the electric locomotive is limited only by the adhesion between driving wheels and rail, and aside from some 15 per cent. greater adhesion possible with the uniform tractive effort provided by the electric locomotive, it is possible with this type of motive power to take momentary advantage of abnormally good rail conditions or to derive full benefit from the use of sand; indeed, tests have been taken with electric locomotives showing as high as 35 per cent. coefficient of adhesion between driving wheels and rail. This point is emphasized as with the greater tractive effort of the electric locomotive it becomes possible to give them a higher tonnage rating for the same weight upon the drivers than would be possible with steam locomotives operating over the same track profile.

There is a marked difference in the speed characteristics of the steam and electric locomotive, and indeed there is also a marked difference in the speed characteristics of different types of electric locomotives. Although this paper is not intended to enter into any discussion of the relative merits of different types of electric locomotives, there is so striking a difference in the several speed characteristics, each of which possess special advantages for certain operating conditions, that Fig. 2 has been prepared contrasting the characteristics of the steam locomotive and the direct-current gearless, alternating-current single-phase geared, and alternating-current three-phase geared electric locomotives. As all types of motive power share in common the fact of a certain critical speed beyond which full tractive effort cannot be maintained, the curves in Fig. 2 have been prepared on the basis of showing the relation between percentage of maximum tractive effort available at speeds higher than the critical speed, ordinates

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being tractive effort and abscissas percentage of critical speed to running speed.

A more familiar presentation is given in Fig. 3, showing a concrete case of a 22 by 30 steam locomotive of the simple type equipped with 57-inch drivers, contrasted with both an alternating-current geared and a direct-current gearless electric locomotive designed for the same tractive effort both maximum and running, but for a higher speed. The contrast of these different

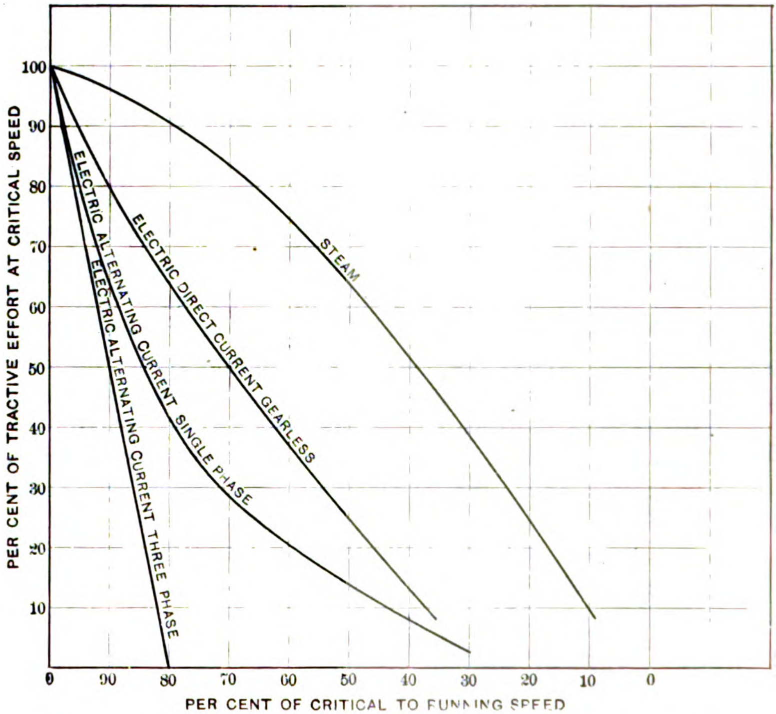

FIG. 2.—Typical characteristics of steam and electric locomotives.

speed characteristics brings out sharply the small speed variation with different tractive efforts delivered by the electric locomotives, this small variation being even more marked in the case of the direct-current gearless than in the case of the alternating-current geared motor working at a lower iron saturation and thus affording a more sloping speed characteristic.

The steam locomotive chosen is typical of those in general use upon our mountain-grade divisions, the tonnage rating in operation

of this particular locomotive being such as to call for a tractive effort of 25,600 pounds on *average* grade and 33,200 pounds on the maximum ruling grade occurring on a certain engine division, thus leaving a margin of 6,300 pounds above the demands of

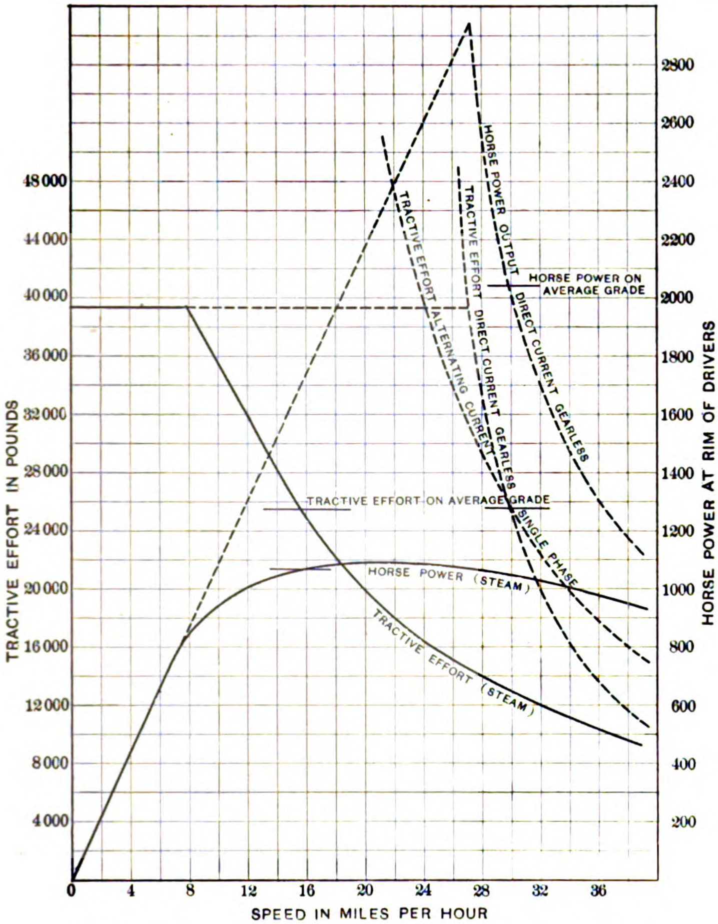

FIG. 3.—Steam and electric locomotive characteristics.

maximum tonnage on maximum ruling grade for starting the train from rest.

The maximum speed available at the different tractive efforts is a matter of boiler capacity, condition of boiler, quality of coal, and efficiency of fireman. The first of these factors, the boiler capacity, can be controlled by properly proportioning the design

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of the boiler to engine capacity, but there are three other factors which the locomotive manufacturer cannot control and two of these factors constitute sufficient cause to warrant a considerable reduction in the *theoretical rated capacity* of the boiler. Thus, referring to Fig. 1, such a locomotive in prime condition carefully fired with the best coal (approximating 14,000 B.t.u.'s) should be able to deliver full tractive effort at 10.6 miles per hour, but in practice it has been found that the average condition of boilers and the average firing provided by the none too conscientious or diligent fireman, cuts the *sustained* boiler output down to not much greater than 75 per cent. of its output under what must be considered exceptionally or momentary conditions, By sustained "output" is meant the output required while ascending the continuous up grades met with on our western mountain divisions. Though full boiler capacity may be attained for short periods, the average performance of all the locomotives on the division on the average up grade will show a marked reduction in capacity from the results obtained in a stationary test or single experimental test runs.

The locomotive characteristic in Fig. 3, has been prepared on the basis of 75 per cent. of the possible boiler capacity in the following manner:

General Constants of Simple Consolidation Locomotive

Diameter of cylinders	22 in.
Length of stroke	30 "
Diameter of drivers	57 "
Heating surface	3397 sq. ft.
Total weight of locomotive	103.5 tons
Weight on drivers	93 "
Weight of tender	61.5 "
Total weight locomotive and tender	165 "

This particular locomotive has been chosen for illustration as it is the type in daily use on the mountain division of one of the largest Western roads.

Under the above conditions, the theoretical tractive effort is 49,500 pounds, of which 39,600 pounds is available at 90 per cent. cut-off. The contents of each cylinder is approximately 6.6 cu. ft. and with four cylinders of steam per revolution and with steam weighing 0.41 pounds per cu. ft. at 170 pounds cylinder pressure, each revolution requires 10.85 pounds steam. With 3397 sq. ft. of heating surface there is a possibility of evaporating six pounds of water per pound of coal when burning

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two pounds of coal per sq. ft. of heating surface, thus giving an available supply of 40,700 pounds of steam per hour when working boilers in prime condition at the full output resulting from perfect firing with good quality of coal. In practice, however, the available steam for sustained output would not be greater than 75 per cent. or 30,500 pounds per hour, thus giving full tractive effort at 46.8 revolutions of the drivers corresponding to 7.93 miles per hour on a 57-inch driver. The "critical speed" of the locomotive is therefore 7.93 miles per hour when working at 75 per cent. of full attainable boiler capacity, and the coal consumed under such circumstances will be 4,360 pounds per hour, corresponding to 1.28 pounds of coal burned per sq. ft.

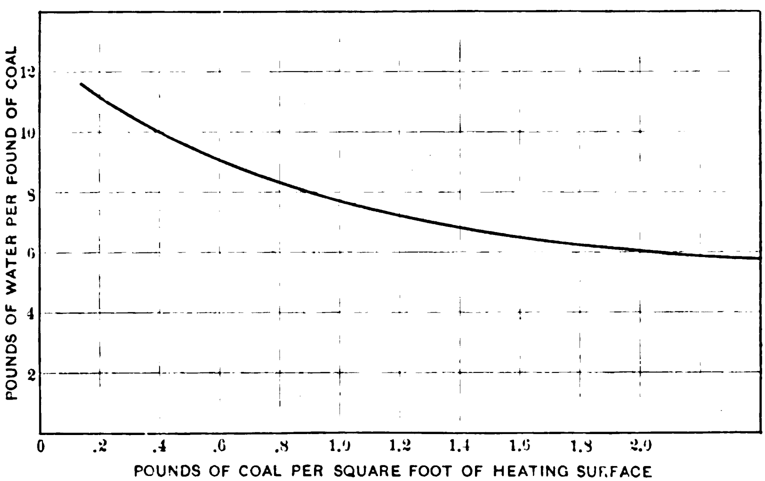

FIG. 4.—Rate of evaporation

of heating surface, at which rate we would expect an evaporation of approximately seven pounds of water per pound of coal.

What might be termed the "performance capacity" of a steam locomotive may be worked out from the speed and tractive effort characteristics given in Fig. 3, using as a basis the 1000 ton-miles trailing load moved per hour on a level or any gradient selected. The prevalence of 2.2 per cent. ruling grade on many of our Western roads perhaps justifies the selection of that figure for demonstration purposes; and the coal consumed, crew wages, and maintenance charges, may all be worked out from the basis of continuous operation per 1000 ton-miles trailing load on 2.2 per cent. grade, these results being shown in Fig. 5.

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Certain assumptions are necessary and are as follows:

Cost of coal		$3.00 per 2000 lb.
Engineer	wages per hour	$0.50
Fireman	" " "	0.35
Conductor	" " "	0.40
Three brakemen	" " "	0.90
Total crew		2.15

Average mileage per locomotive per year, 36,500.
Total maintenance including round house charges, $5,000.00.
Maintenance per locomotive mile actually run, 13.7 cents.
General locomotive constants are the same as previously given.

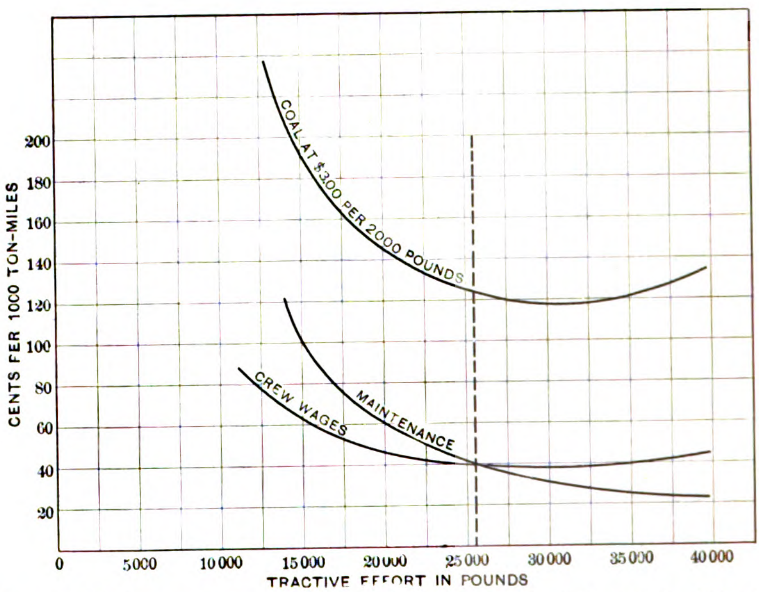

FIG. 5.—Performance capacity steam locomotive (simple) grade 2.2% (up)

Having broadly outlined the performance characteristics of the simple consolidation engine frequently met with in heavy grade operation, it becomes necessary so to proportion the constants of the electric locomotive, assumed to replace it, so as to gain the greatest benefit from the different inherent characteristics of the latter type of motive power.

Referring to Fig. 2, it is evident that with the small speed variation of the electric locomotive, and due to the fact that its motive power is separate from its unlimited source of power generation, it is possible to consider radical changes in the method of moving freight, more especially on mountain-grade divisions.

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It has become a partly accepted fact that the electric locomotive characteristic should be so proportioned as to enable it to operate trains at a high rate of speed on level track and at a much slower speed on grades, in fact conforming with present steam practice in this respect. The writer would again point out that steam railroading to-day is in reality steam locomotive practice in that the speed possibilities of different track divisions are restricted to a large extent by the limitations of the steam locomotive. In other words, the only reason why it is common practice to run at very low speeds on mountain-grade divisions instead of continuing the high speeds in vogue on more level portions, is because a steam locomotive cannot be built powerful enough to supply the heavy tractive effort required at any higher speeds than those now in vogue.

Railway economies teach us that the lowest cost per 1000 ton-miles is obtained when operating the greatest train weight at the highest speeds, and Mr. J. J. Hill's well known saying to the effect that " Expenses are per train-mile and receipts per ton-mile ", is only partly true, as the time consumed in hauling the train one mile enters as a most vital factor.

Considered broadly, the one expense in train operation that is fundamental is the cost of fuel, this factor being influenced only by the economy of the fuel-burning plant. Other expenses, such as locomotive maintenance, crew wages, etc., are affected entirely by the method of operation, and no radical departure from present methods is to be looked for until the coming of a type of motive power which offers possibilities not equally enjoyed by the steam locomotive.

This point is further illustrated by reference to the operating sheet of one of our greatest Western roads using the simple consolidation locomotive previously described.

SPEED RELATIONS. ROAD " A " MOUNTAIN DIVISION

	UP GRADE	DOWN GRADE
Schedule speed	7.35 miles per hr.	12.5 miles per hr.
Average speed while running	12.1 " " "	20.0 " " "
Number stops per mile	0.177 " " "	0.149 " " "

The average schedule speed of a number of trains, including all layovers due to the despatcher or failure of motive power, as obtaining on another mountain division of a different road, showed values as low as 6.7 miles per hour up grade. In general it may be stated that the freight movement over mountain divisions is effected at very low schedule speeds, and the cause is evident

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from an inspection of the steam locomotive characteristic. Except for the fact that curves are usually of shorter radius on heavy grades than on levels, there is no reason for the slower speed of trains, provided a type of motive power is available that is capable of supplying great draw-bar pulls at high speeds. It is just this characteristic which the electric locomotive possesses to an almost unlimited extent, and such locomotives can be built which are even more powerful and operate at higher speed than can be utilized at present.

For example, the simple consolidation locomotive considered is capable of sustaining a tractive effort of 25,600 lb. at a maximum speed of 15.4 miles per hour, and weighs 165 tons with tender, while a single New York Central electric locomotive of the 6000 type is capable of delivering the same tractive effort at approximately 37 miles per hour, and the weight is only 100 tons. The Central locomotive is of course designed for moderate speed passenger service and could not be run continuously at such a large output, but it is cited only as an example of a well-known electric locomotive having an enormous horse power capacity, although in this respect it is but the forerunner of other electric locomotives having still greater outputs. Owing to the fact that such units may be run in groups of two or more and still be perfectly under the control of a single operator, the advantage of very large single units is somewhat modified, and the introduction of the electric locomotive may also introduce new ideas as to the size and construction of single hauling units.

The electric locomotive may be equipped with motors of several different types each having characteristics best qualifying it for certain classes of work. Fig. 6 and Fig. 7 illustrate the usual speed, torque, and efficiency curves of two typical motors, the direct-current gearless and the alternating-current single-phase geared type. The type of motor to be adopted is a matter requiring full local knowledge of the conditions obtaining in each individual instance before a proper selection can be made. All three of the available motors—direct current; alternating current single-phase; and alternating current three-phase, possess the one needed characteristic of great output per pound and hence the arguments advanced for the substitution of the electric for the steam locomotive are general in character and do not apply strictly to locomotives equipped with any one type of motor to the exclusion of all others. As the direct-current gearless motor can be built in the largest sizes, is the best

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understood, and is in successful operation upon a very important division of one of the largest steam roads, it is heie chosen as the equipment of a typical electric locomotive.

The large output, 840 h.p. for one hour and 400 h.p. continuous, shown in Fig. 6, illustrates what can be accomplished with this type of motor. The output of the complete locomotive is dependent upon the number of motors permitted with the construction adopted. Thus, such a four-motor equipment is capable of delivering a tractive effort of 56,800 lb. at a speed of

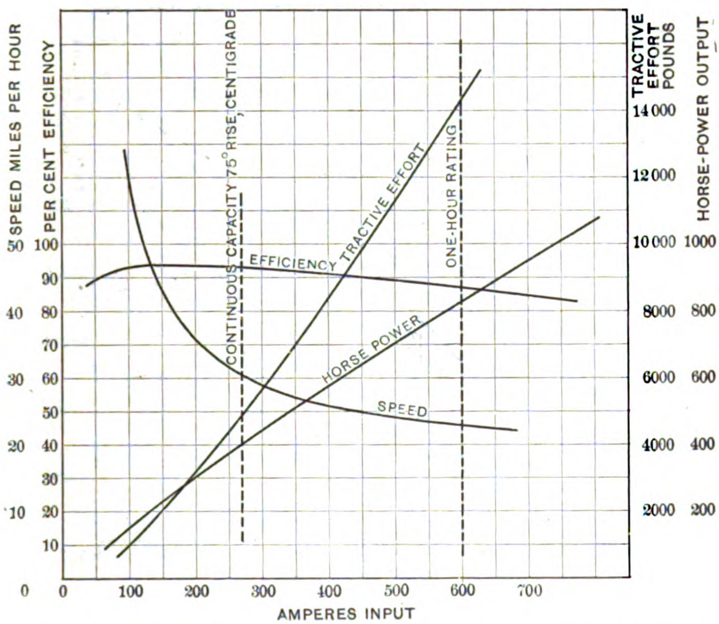

FIG. 6.—Direct-current gearless motor characteristics, 1200 volts

23 miles per hour approximate (depending upon the voltage) while the efficiency of conversion at this output would be 87 per cent., rising to a maximum of 93 per cent. at higher speeds and lower tractive effort. Another form of construction, say one similar to that employed in the largest Mallet compound. would permit the use of two four-axle articulated trucks, providing an equipment of eight motors and an output of 113,600 lb, at a speed of 23 miles per hour.

The same motors could readily be rewound to give the same tractive effort at *considerably increased speeds* if desired, without

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materially increasing the internal losses of conversion. Bearing fully in mind the fact that a single operator has this enormous energy under perfect control, and that such a locomotive could do the work of two or more Mallet compounds and several locomotives of the simple consolidation type, and it becomes evident that in the electric locomotive there are tremendous possibilities of improving present methods of railway operation as now conducted with the steam locomotive. Carrying the thought a step further and appreciating that several such electric locomotive

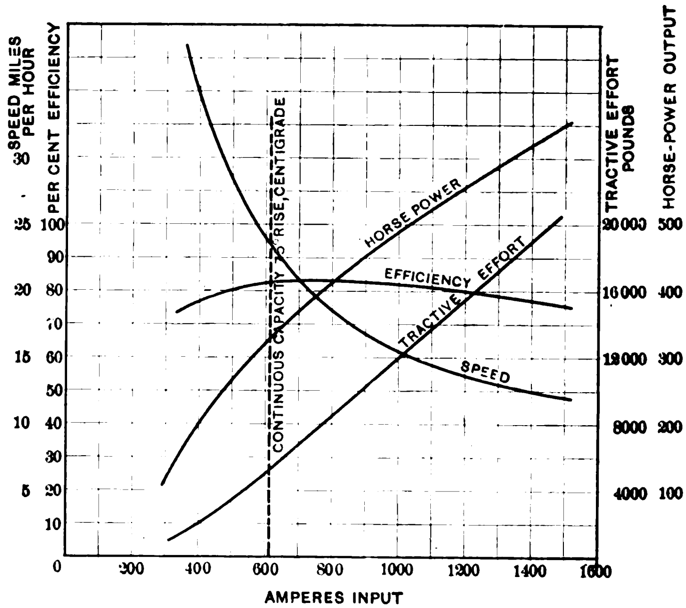

FIG. 7.—Alternating-current single-phase motor characteristics, 25 cycles, 375 volts

units may be operated in a group forming a combined unit, it becomes evident that in the electric locomotive we have a type of motive power capable of furnishing any output in tractive effort and speed that present or future operating conditions may demand.

Returning to the direct comparison of the simple consolidation and electric locomotive, Fig. 3, was plotted on the basis of a speed of 30 miles per hour for the electric and 15.4 miles per hour for the steam locomotive, giving in each instance a tractive effort of 25,600 lb. at the rim of the drivers. Though the elec-

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tric locomotive could very readily be designed to give the same tractive effort at a higher speed, 30 miles per hour was assumed as the highest speed permissible due to the alignment of the track on heavy grades.

To plot a performance capacity curve for the electric locomotive, certain further assumptions are necessary.

Type of equipment, direct-current gearless motors.

Weight of total locomotive		125 tons
" on drivers		100 "
Engineer	wages per hour	$0.50
Conductor	" " "	0.40
Three brakemen	" " "	0.90
Total wages of crew		1.80

Efficiency of transmission rail to bus-bar, 70 per cent.
Maintenance of locomotive, 5 cents per mile run.

The train crew is so divided as to permit the location of a brakeman in the engineer's operating cab.

The cost of electrical power must in this instance be most arbitrarily assumed, owing to the widely different cost of coal, possibility of water power, etc., obtaining in different localities. As the cost of coal for steam locomotives will also vary greatly as to price and quality, it has been assumed at $3.00 per 2000 pounds, and a cost for electric power of one-half cent per kilowatt-hour is based upon using the same price and quality of coal. As it is further assumed that an entire engine division of say 150 miles is to be electrified, it gives promise of a 24-hour load-factor of 50 per cent. and this figure has been taken. Approximating the first cost of installation of the generating station at $100.00 per kilowatt, and allowing ten per cent. per year for interest and other fixed charges, the cost of power is brought up to possibly $0.0075 per kilowatt-hour at the station bus-bar. Other conditions obtaining will in a given instance modify the figures arrived at, but for purposes of demonstration $0.0075 is a conservative estimate, and such a figure is needed to compare the cost of power with the fuel item in steam-locomotive performance.

The effect of increased speed on cost of operation is clearly shown by comparing the performance capacity curves of the steam and electric locomotives, Figs. 5 and 9.

It will be observed that the reduction in the operating expenses is effected in the two items of crew wages and maintenance of locomotives, and that the cost of fuel remains practically

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unchanged. This is as it should be, as the cost of fuel in the case of steam locomotives or power with electric locomotives is the only fundamentally necessary expense in train movement. Overcoming train friction and raising a train up grade against gravity represents useful work performed, and this work is accomplished at an expenditure of approximately four pounds of coal per horse power-hour at the drivers with simple engines and 2.66 pounds of coal per horse power-hour at the drivers with electric locomotives, including all intervening losses between rail and

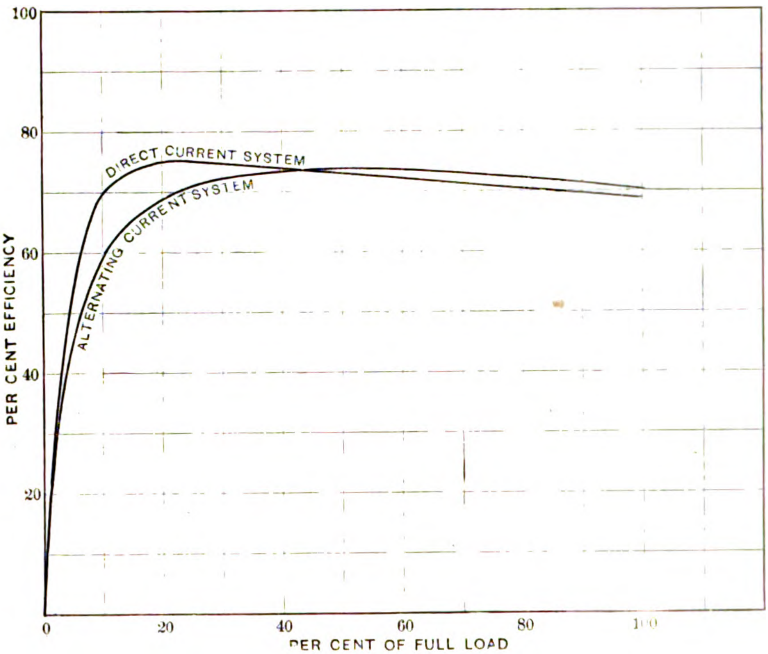

FIG. 8.—Efficiency of distribution generator to rail

generating station bus-bar. The speed at which this work is performed, therefore, does not affect the cost of fuel or power, it being assumed that the motive power for the various speeds is so proportioned as to operate at the point of greatest economy.

Thus with coal at $3.00 per 2000 pounds in each case, the steam locomotive can generate a horse power at the drivers at an expenditure of $0.006 as against $0.0039 for fuel alone with the electric. The two figures are not directly comparable, as to the cost of fuel for steam locomotive operation must be

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added the extra cost of hauling, which on grade divisions may constitute a large percentage of its original cost; and the waste incident to handling and storing in many bunkers along the tracks. In addition, there is a considerable quantity of coal burned under the boilers of steam locomotives standing idle or coasting down grades, which will be shown later, may equal ten per cent. of the total consumption in main line freight movement and much more in the case of helpers and switching engines. If, therefore, coal be delivered at the engine division terminal

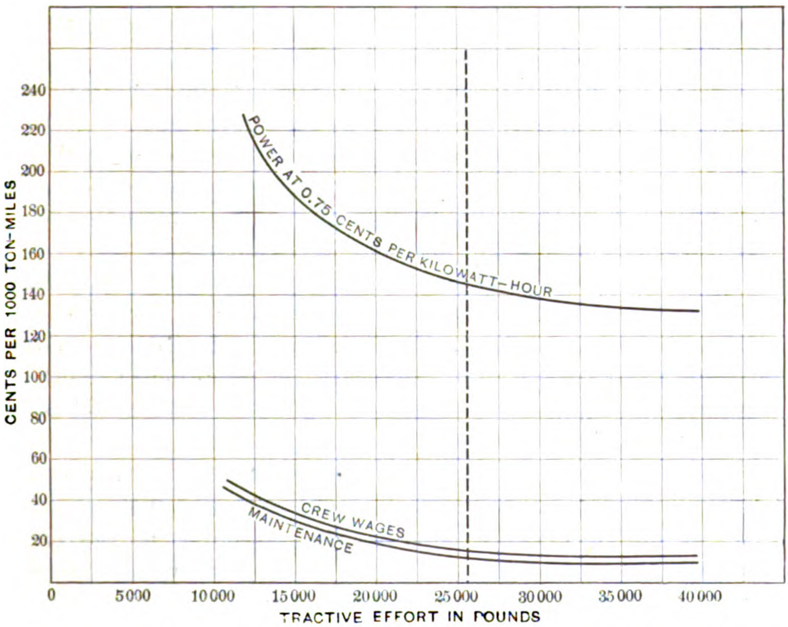

FIG. 9.—Performance capacity electric locomotive (Direct-current gearless) grade 2.2% (up)

at $3.00 per ton, the actual cost on the tender will be considerably in excess of this figure, and due allowance must also be made for the coal wasted, burned or otherwise, and not producing useful brake horse power-hours at the rim of the drivers.

In the electric system also, besides the allowance made in distribution losses in arriving at 2.66 pounds coal burned per horse power-hour at the rim of the drivers, there will be an additional charge for labor and fixed expenses incident to power-house operation and first cost. The electric system, however, is not

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restricted to the use of high-grade fuel and coal of an inferior quality, and much lower cost, such as lignite, can be utilized, besides the large opportunities for cheap power presented by the water powers generally available on mountain divisions.

The saving or deficit in the power item with electric as contrasted with the fuel item of steam locomotive operation must, therefore, be largely determined by the local factors entering into the case. A common cost of $3.00 per 2000 pounds for coal is taken in this discussion; it is rather favorable than otherwise to steam locomotive operation, as coal can be dropped into the bin of a power house located at a division terminal at less expense than it can be hauled up a severe long grade and distributed in several pockets along the route.

It is evident that the cost of fuel or power, being fundamental, constitutes a fixed item in the total cost of operation while the other two items, crew wages and maintenance expenses, will be determined solely by the method of operation and the excellence of motive power used. We have become so accustomed to consider that fuel, crew wages, and engine maintenance each constitute approximately ten per cent. of the total cost of operating a railway that we rather lose sight of the fact that two of these items are a theoretically needless expense and subject to considerable modification in practice with the adoption of another type of motive power possessing characteristics which will permit making radical changes in operating methods.

While the figures shown in Figs. 5 and 9 indicate a certain relation among the three items of fuel, crew, and maintenance expense, this is not the true relation obtaining in practical operation for the reason that the values given in the curves assume continuous operation up grade under the conditions outlined. Unfortunately, train crews must be paid full value per mile whether the mile be up grade or down, and with steam locomotives there is also a considerable loss in fuel resulting from engines standing or running light which must be also taken into account; hence it becomes necessary to modify the figures arrived at, and for this purpose certain references must be made to current railroad practice on mountain-grade divisions in order to arrive at the proper tonnage relations, schedule speeds, etc., obtaining in up-grade and down-grade operation.

Previous figures have been given showing that the schedule speed on several mountain divisions is approximately 50 per cent. of the average running speed and this figure is assumed in

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the following statement of cost of operating 1000 ton-miles with steam locomotives, averaging the cost of up- and down-grade running. Owing to the higher schedule speed of electrically operated trains, resulting in fewer meeting points with the same tonnage handled, and due to the absence of forced stops to take on fuel and water, etc., it is assumed that with electric motive power the schedule speed may be 60 per cent. of the running speed.

With the electric locomotive standing, or coasting down grade, there is no demand whatever made upon the generating station, and hence the only expense carried through these periods is that for train crew and a certain amount for maintenance. On the other hand, with the steam locomotive there is a considerable amount of fuel burned and water wasted when standing at sidings and when coasting. In the case of mountain railroading with its frequent and prolonged delays, this waste may reach considerable proportions.

The following results of a carefully conducted series of tests will illustrate this point. Two test locomotives and trains were operated over a mountain division under regular service conditions—steam and fuel consumption, duration of delays, etc., being carefully noted. The total work expended up grade was 5700 horse power-hours at the rim of the drivers including allowance for 1.54 per cent. average grade and seven pounds per ton track and curve friction. The total water evaporated on the trip divided by the total horse power-hours gave a steam consumption of 36 pounds per brake horse power-hour at the rim of the drivers. Indicator cards taken upon the engine in question at all cut-offs up to 90 per cent. showed that the greatest steam consumption did not exceed 32 pounds per indicated horse power-hour, or 35.5 pounds per brake horse power-hour, allowing ten per cent. internal engine friction. Values as low as 23 pounds of steam per indicated horse power-hour or 25.5 pounds per brake horse power-hour were recorded for the average cut-off of 40 to 50 per cent. used throughout the run. A third and fourth series of tests conducted up the same grade gave similar results, except that the values were slightly higher than those quoted, showing that there was a considerable loss of water unaccounted for by indicator cards and useful work performed.

Operating down grade, it was necessary to accomplish 1110 horse power-hours on account of the somewhat broken profile,

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and again the water consumption showed on two trips 57.7 pounds of steam per brake horse power-hour, and on two subsequent trips 66.5 pounds, values entirely unaccountable on the basis of useful work performed.

During all tests the usual service delays occurred, and as the traffic on the road in question was very much congested, these delays constituted a considerable proportion of the total elapsed time. In fact during the runs up grade the trains were in motion but 66 per cent. of the total elapsed time, and down grade the trains were in motion from 52 per cent. down to 40 per cent. of the total elapsed time. As these delays were frequent and undetermined, it was necessary to maintain full steam pressure while waiting for the momentarily expected release from the block, hence the waste of fuel and water was considerable. Averaging this waste at 400 pounds per hour, at which low rate of consumption the water evaporation would approximate ten pounds of water per pound of coal burned, or 4000 pounds of water evaporated per hour, and reducing the total water consumption measured by the waste losses thus obtained, the steam consumption in eight different tests up and down grade ranged 34.7 pounds, 32.4 pounds, 28.1 pounds and 25.3 pounds, etc., water per brake horse power-hour. These values are fairly commensurate with results of indicator cards taken, and, with the type of engine used and under the operating conditions obtaining, an allowance of 400 pounds of coal stand-by losses per idle locomotive-hour seemed not too great a value to allow, and this figure has been taken in subsequent calculations.

Locomotive performance capacity curves may therefore be plotted which will show approximately the true relation between the several items of fuel, crew wages, and motive power maintenance, by adhering to the following assumptions:

Ratio schedule to running speed up-grade steam locomotive,	50 per cent.
" " " " " electric "	60 per cent.
Schedule speed down-grade steam	15 miles per hour.
" " " " electric	18 miles per hour.
Cost of coal	$3.00 per 2000 lb.
" " electric power	0.0075 per kw-hr.
Efficiency of distribution	70 per cent.
Crew wages per hour steam	$2.15
" " " " electric	$1.80
Maintenance locomotive steam	$0.137 per mile.
" " electric	$0.05 per mile.
Fuel waste per idle hour steam	400 lb.

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An inspection of the performance curves shows that in practical operation the fuel expense approaches more nearly to the value of the other items considered, instead of being greatly in excess of them as indicated in the theoretical performance

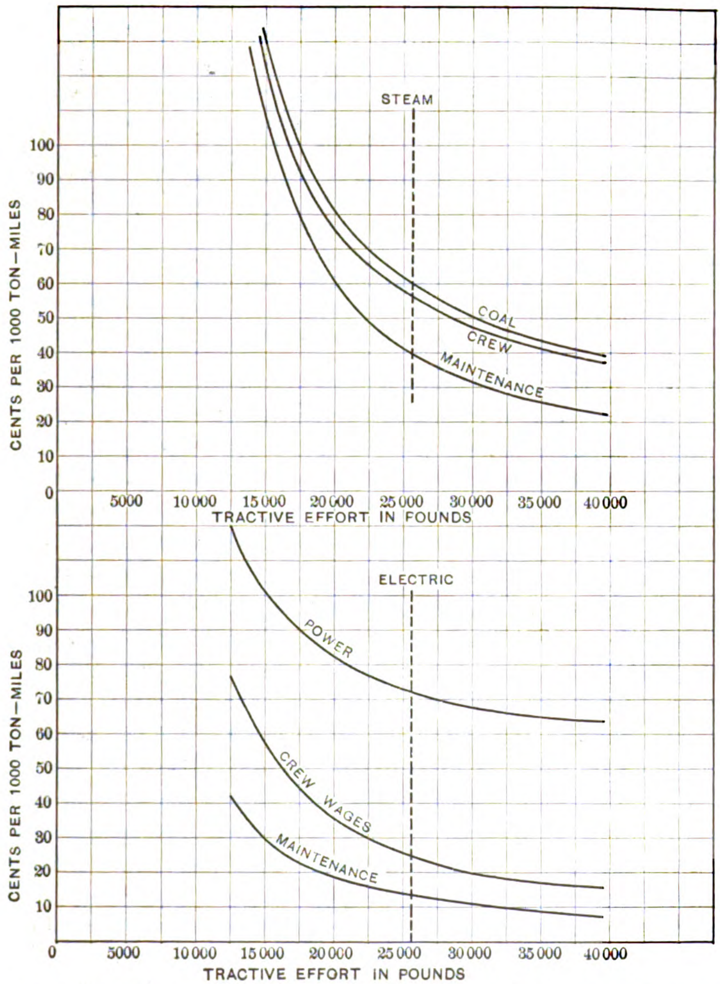

FIG. 10.—Tractive effort in pounds. Service capacity steam and electric locomotives average of up and down 2.2% grade

curves, Figs. 5 and 9, showing up-grade operation only. For operation on lesser grades than 2.2 per cent., all items are reduced and the total and subdivided comparative costs are given in the following table and in Fig. 11.

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COMPARATIVE OPERATING EXPENSES PER 1000 TON-MILES STEAM (SIMPLE) AND ELECTRIC LOCOMOTIVES

AVERAGE OF UP- AND DOWN-GRADE OPERATION

	Steam Locomotives			
Grade	½%	1%	1½%	2%
Coal	15 cents.	25.5 cents	38 cents.	53 cents.
Crew	13.5 "	24 "	36 "	50 "
Maintenance	10.5 "	17.8 "	26 "	36 "
Total	39 "	67.3 "	100 "	139 "
	Electric Locomotives			
Grade	½%	1%	1½%	2%
Power	20 cents	35.5 cents	50.5 cents	66 cents.
Crew	7.2 "	12.2 "	18 "	24 "
Maintenance	3.6 "	6.2 "	9.0 "	11.9 "
Total	30.8 "	53.9 "	77.5 "	101.9 "
	Saving effected by electric operation			
Grade	½%	1%	1½%	2%
	8.2 cents	13.4 cents	22.5 cents	37.1 cents

A study of the above table is most instructive, as it shows that while the percentage saving with electric operation is approximately the same whatever the ruling grade, yet the actual money saving is much greater on the heaviest grades. As about the same investment must be made in each case for distribution system including third-rail or overhead trolley, sub-stations, etc., the inference must be drawn that heavy-grade divisions present a more attractive field for electrification than level sections when considered from the purely economic standpoint. There are other items of saving and other reasons for electrification which may be more or less controlling in individual cases, but it seems possible to make the broad statement that the mountain-grade division offers a particularly attractive field for the electric locomotive, and its introduction should be the means of affecting such economies in both freight and passenger transportation as to pay a satisfactory return upon the investment required.

So far, the matter has been viewed from the standpoint of comparative operating expenses for a given tonnage moved. There is another argument for electrification which may in certain instances be of a much more controlling nature. Most of our mountain roads are single track and transcontinental tonnage has so increased as seriously to congest these mountain divisions. The heavy trains of the plains, weighing 2000 to 3000 tons, must be split up into units of about 1000 tons in order that the present steam engines, operating double and even triple, may haul them

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over the heaviest grades. The slow speed obtainable makes the number of trains on a mountain division large, the meeting points frequent, and hence, however good the despatching system employed, there will of necessity be a considerable amount of lost time introduced. Add to this the failures of motive power being worked to its limit, and there is reason for the claim

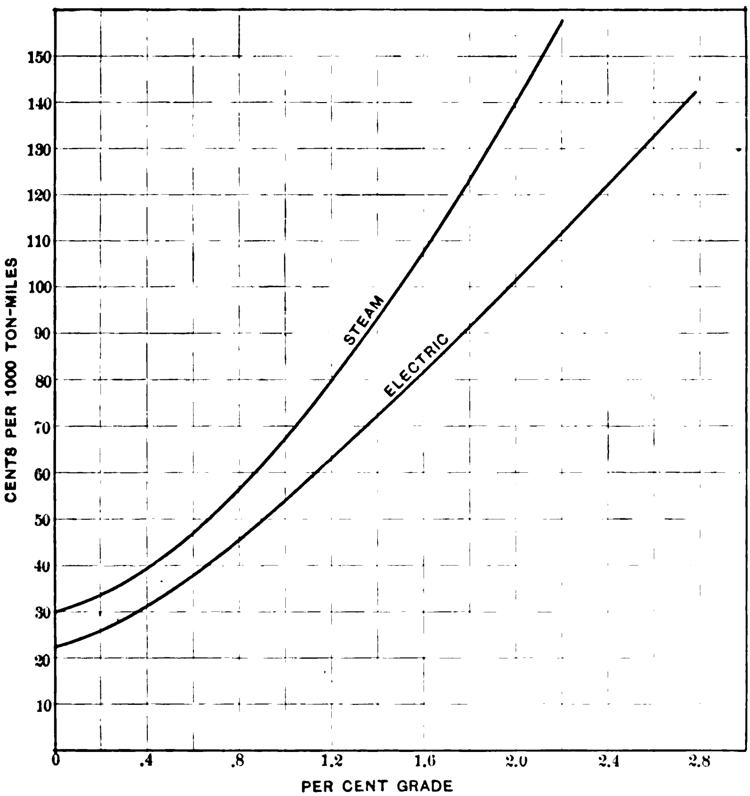

FIG. 11.—Service capacity of steam and electric locomotives average both directions and any gradient

that the tonnage capacity of the division will be greatly increased by the introduction of electrically hauled trains.

Lest the writer be accused of unfairness in selecting the simple engine for comparison, it is proper to touch upon the economies effected with the use of the compound locomotive and also by the introduction of such coal-saving devices as superheaters and feed-water heaters.

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Reference to Fig. 13, shows a saving in water consumption per horse power of approximately 20 per cent. with the compound locomotive, but in spite of this generally accepted saving the simple locomotive still rules the mountain division after repeated trials of the compound. Not being an ardent supporter of either type of locomotive, the writer leaves the battle of the simple and compound to their enthusiasts, commenting only upon the fact that, except in the case of the Mallet compound, the arguments for the compound are based upon fuel economy only.

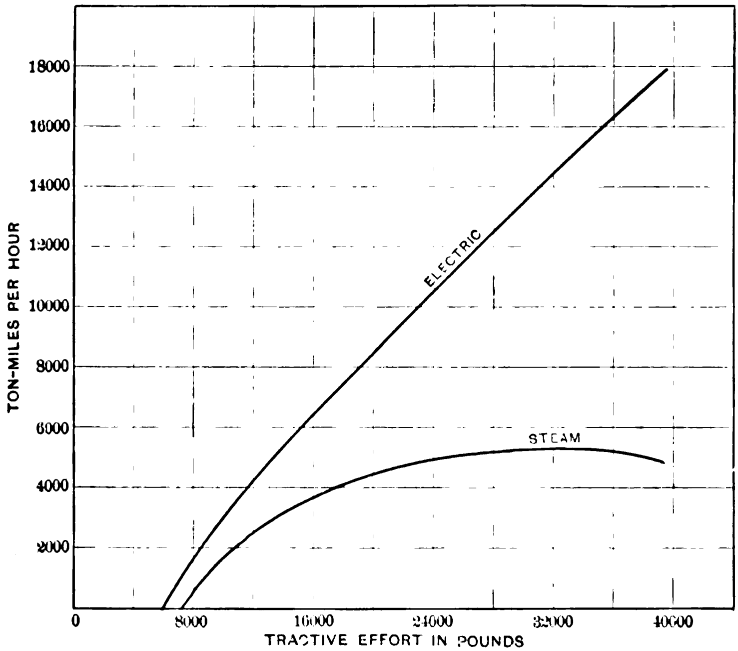

Fig. 12.—Hourly tonnage capacity of steam and electric locomotives up 2.2% gradient

The latest Mallet compound, weighing 413,000 pounds, is the largest steam locomotive yet built, and is of particular interest owing to the enormous boiler which such a construction permits. With a total heating surface of 5300 sq. ft. we should expect an evaporation of 63,600 pounds of water for a short period and possibly 48,000 pounds water continuously. With a possible evaporation of six pounds of water per pound of coal, this would necessitate the burning of 8,000 pounds of coal per hour, re-

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quiring the best efforts of two firemen if maintained for several hours. Assuming a steam consumption of 22 pounds per brake horse power-hour, such a locomotive should give a sustained output of 2180 horse power at the rim of the drivers, and this with a weight with tender of approximately 300 tons, or three times the weight of an electric locomotive of the New York Central 6000 type giving the same horse-power output.

The two locomotives are, of course, designed for entirely

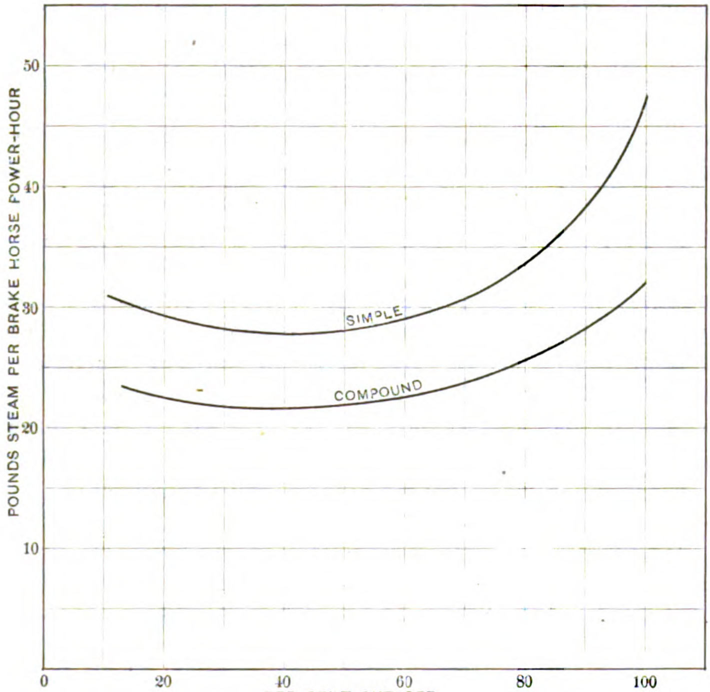

FIG. 13.—Steam consumption simple and compound

dissimilar classes of work; but it is not unfair to compare them on a horse-power basis as it is the huge boiler of the Mallet that is remarkable, and upon this basis the selling price of the two machines is approximately the same.

The comparative cost of electric and steam locomotives is generally considered as very favorable to the steam units, but reversing the usual methods and comparing the cost of the electric with that of the steam locomotive or locomotives required to replace it, may reverse the relations. The electric locomo-

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tive requires no more than casual inspection, can be side-tracked indefinitely and still be ready for instant operation at full capacity, can run 24 hours without a stop, if necessary, and all these advantages and others offers a guarantee for a much greater annual mileage than is possible with its steam competitor. Then, too, compare the cost of a group of steam locomotives (no single unit could be designed to give the output) capable of delivering even 4000 h.p. continuously with a single electric unit of this output, and the difference in cost is not great. It may be stated broadly that for a given gross annual ton-mileage moved, the cost of steam locomotives may be even greater than the cost of the electric units replacing them.

The term " horse power " is perhaps not fully appreciated by the steam railway fraternity. When the statement is made that a certain electric locomotive is rated at so many horse power output, it does not leave the impression it should. The horse power output of a locomotive is a direct measure of its capacity to do work, and while the tractive effort available governs the tonnage of the trailing load, it is the product of the tractive effort times the speed at which it is available, or in other words, the horse power output, that measures the hourly tonnage capacity of the locomotive upon which the crew expenses of the entire train depends. Hence the great claim for recognition of the electric locomotive lies in its great horse power output, that is, its ability to carry full tractive effort or to slip its wheels at speeds two or three times greater than can be done with any steam locomotive yet built.

Superheating promises something in fuel economy, as does the introduction of feed-water heaters. Such improvements, together with the adoption of the four-cylinder locomotive, either compound or simple, must necessarily call for more expense to maintain and less reliability in operation. In fact, superheating in stationary boiler plants has given much trouble, and excessive superheating has not been a complete success even when used with turbines, with which superheating has given the best results. Judged from stationary engine practice, it seems fair to assume that the amount of superheat in locomotive practice must be moderate and result in small benefits to be secured.

The feed-water heater is also a coal-saving device and should prove to be worth its added complication as soon as it is commercially developed.

As against the reduction in fuel expenses promised by the use

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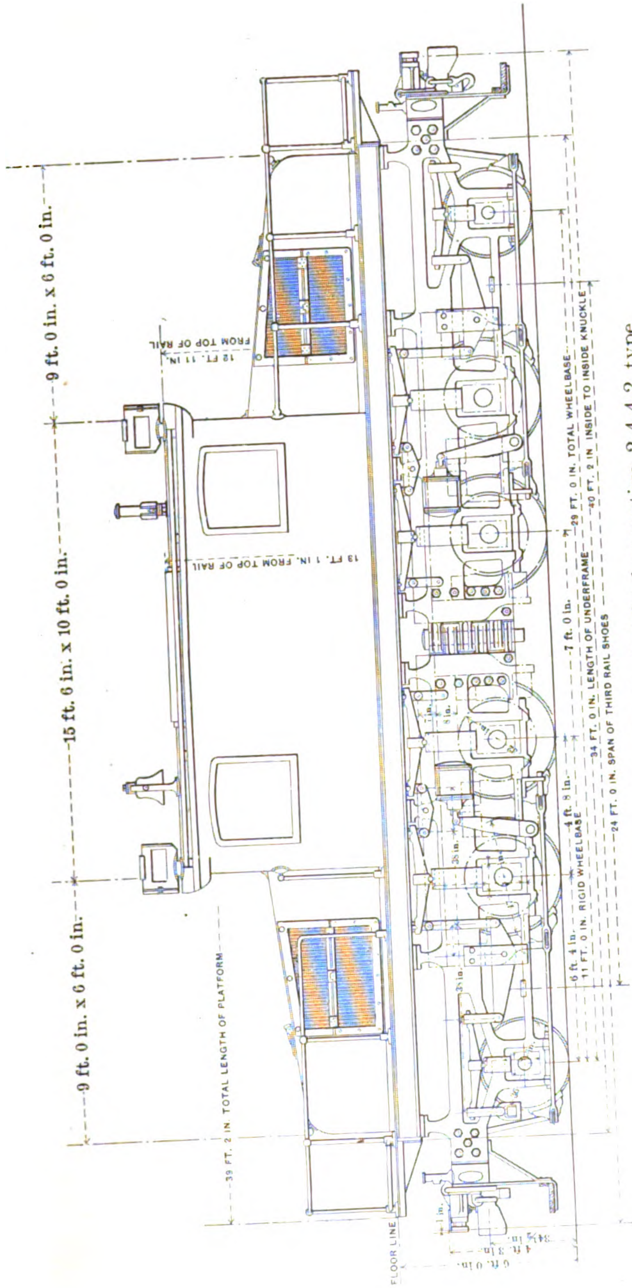

FIG. 14.—Typical electric freight locomotive 2-4-4-2 type

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of the compound locomotive fitted with superheaters and feed-water heaters, the electrical engineer has up his sleeve the great possibilities offered by regeneration of power while electrically braking on mountain-grade divisions. The amount of power saved by this means may in certain installations amount to as great a percentage of the total as is the saving affected in coal expenditure with steam locomotive by compounding and providing superheaters and feed-water heaters. Such an electrical saving is of course restricted to heavy-grade divisions, but the feasibility of electric braking by regeneration is unquestioned. Indeed with three-phase induction motors regeneration is automatic, the motors being perfectly reversible and returning energy when operating down grade with no change whatever in their connections. Other types of motors may be adapted for regeneration with slight modifications in the control system.

The chief advantage of regeneration lies in the assurance it offers of greater safety in operating on heavy grades. The present method of braking, by friction between wheel and shoe, results in overheated parts, breakages resulting therefrom and consequent danger of derailment. The descent of a long heavy mountain grade is accompanied by the shoes and wheel rims becoming heated to a dull red, while the introduction of the electric locomotive offers an opportunity of holding the train in whole or in part by means of the same motors used to haul it up grade, and thus eliminating one of the greatest sources of danger in mountain railroading.

All of our railway managements have felt the need of establishing a so-called express freight service comprising a light train operating at much higher speed than is the case with the bulk of the freight movement. It is well known that the cost per 1000 ton-miles for moving express freight is very much higher than in the case of low-speed freight. An inspection of Fig. 3, illustrates the reason for this. The steam locomotive is essentially a slow-speed unit when delivering its full tractive effort; that is, a tractive effort equal to 22 per cent. of the weight upon the drivers, and high speed is only obtained at the sacrifice of tractive effort. Hence a high-speed freight train is of necessity a lighter train than could be handled over the same profile by a given locomotive, and the crew and maintenance expense is therefore large. That such a class of service is nevertheless profitable or at least necessary is evidenced by the continuance of the practice and the proposed introduction of elec-

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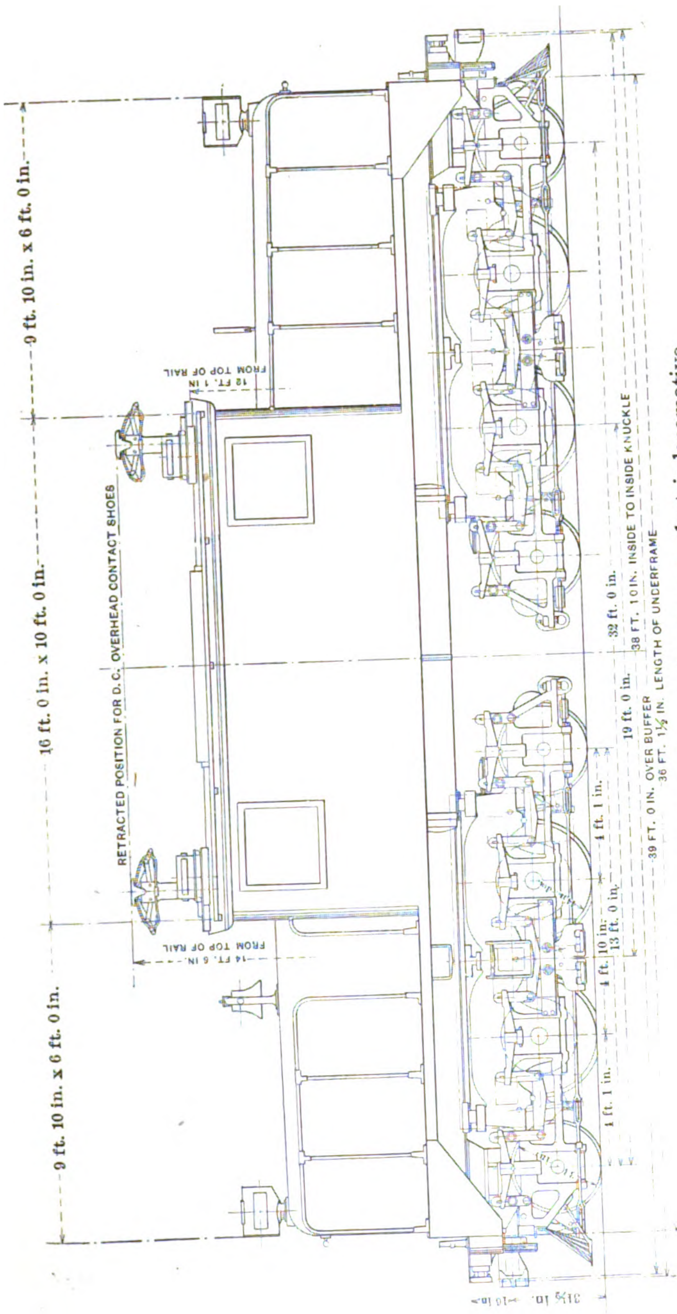

FIG. 15.—Typical high-speed passenger electric locomotive

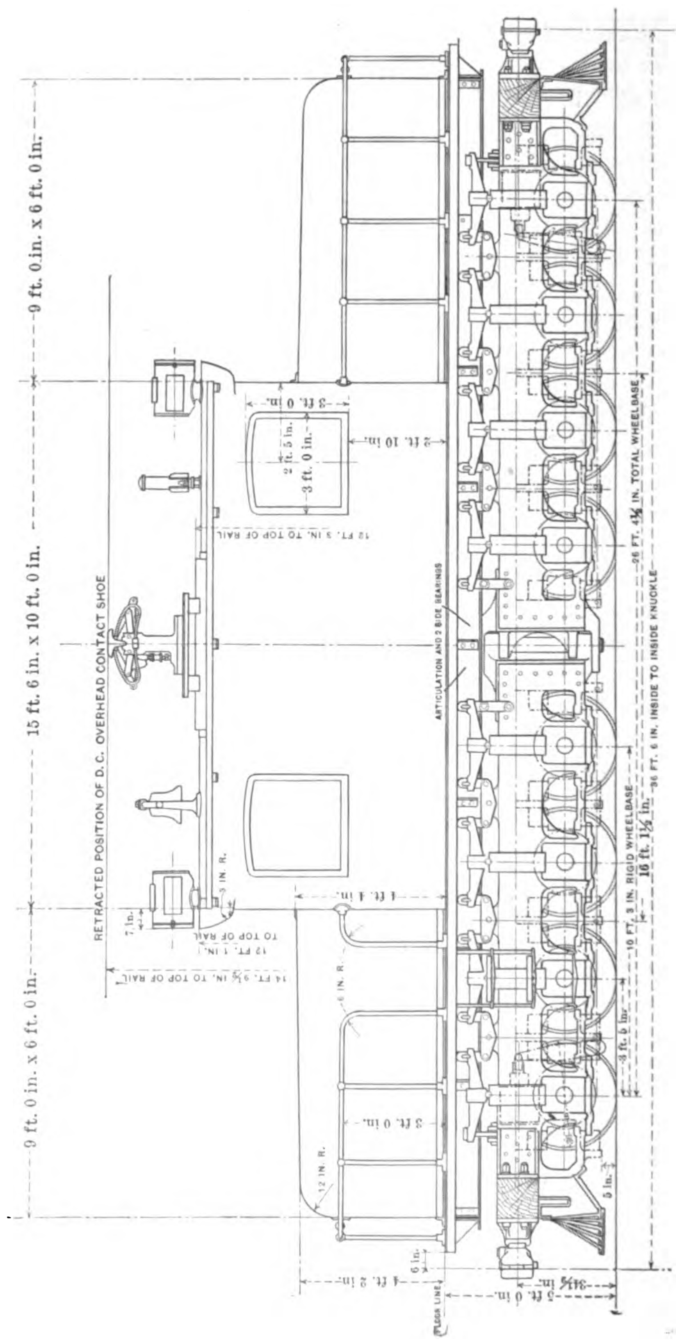

FIG. 16.—Typical electric locomotive heavy freight 0-8-8-0 type

tric locomotives, in effect, makes all trains fast freights, gaining the benefits of such a service without incurring the penalty of increased operating expenses inherent to steam operation.

In this paper the writer has attempted to outline some of the fundamental reasons for the electrification of steam roads; the figures submitted are used for illustrative purposes only and are not intended as being directly applicable to any concrete case. Many of the points touched upon, such as steam locomotive improvements, compound versus the simple, and the comparative advantages of different types of electric locomotives, etc., could all be treated in separate papers by themselves, so replete with interest are the different points raised. Rather than befog the main question at issue, which is the electrification of steam roads, detailed proof of many statements made has not been attempted, as the introduction of such proof would unnecessarily extend a paper already too long. Nor does the writer believe that the time is ripe for the electrification of steam roads at large; indeed, the electrical enthusiasts would be hard put to it if called upon to show reason for the electrification of many branch steam lines carrying a small tonnage at infrequent intervals. There are, however, certain divisions of our steam railways which, either on account of their broken profile or heavy traffic, offer an opportunity to introduce a superior type of motive power which will effect such economies in operation as to provide adequate return on the investment required for the electrification. There are still other divisions where a much desired increase in the track-tonnage capacity can only be effected by double tracking so long as the steam locomotive is adhered to as the type of motive power used. Double tracking a mountain-grade division is often a matter of enormous expense, and electrification of the single track may relieve the present traffic congestion at a moderate cost.

On mountain-grade divisions the subject of regeneration with electric locomotives should receive very careful consideration, not so much on account of the saving in power which it may effect, but rather on account of the greater safety of operation which it guarantees by eliminating the serious defects of holding trains on heavy grades by wheel and shoe friction. Finally, there are the many incidental advantages to be gained with electrification which cannot be predicted with any accuracy, as they result from changes in operating methods sure to follow the introduction of a type of motive power not subject to the service limita-

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tions of the steam locomotive. No attempt has been made even to approximate the saving effected in engine supplies, roundhouse expenses, elimination of water supply with its often attendent expensive purifying outfit, and the many items incident to steam locomotive operation. These items are incidental and seldom assume an importance sufficiently great to class them as fundamental, though the difficulty of procuring good water, even with purifying plants, may approach very closely to being a controlling factor in certain cases.

The freight-car shortage problem itself is a very serious one at certain times of the year on some roads, and as the total freight-car mileage can be increased with the higher speeds provided with electric locomotives, it should result in the saving of a considerable expense now incurred for rental of foreign cars, or even increase the gross receipts by the movement of tonnage which more available cars would make possible.

The subject of the electrification of steam roads is, therefore, a very broad one, and while this paper has been devoted largely to a discussion of operating expenses as affected by the different characteristics of the two types of locomotives, it has been done to illustrate the advantages resulting from increased locomotive capacity. The keynote of electrification is *capacity;* by approaching the problem from this standpoint only can full benefits be obtained.

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A paper read at a meeting of the Schenectady Branch of the American Institute of Electrical Engineers, April 26, 1907.

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(*Subject to final revision for the Transactions.*)

CONSTANTS OF CABLES AND MAGNETIC CONDUCTORS

BY ERNST J. BERG

In the paper on "Line Constants, Etc.,"* equations were given for the inductance and capacity of the parallel conductors used in transmission lines. The formulas given were sufficiently accurate for any transmission line calculations where the distance between wires is large compared with their diameters; where, however, the diameters are comparable with the distance, as is often the case with cable transmissions, it is necessary to use the strictly theoretical expression.

In looking up the available literature on this subject, one is surprised at the great number of different formulas given. This is particularly the case in reference to the inductance formula which generally consists of two terms, one of which is constant and is usually given as 0.5, 0.75, or 1; the other a logarithmic function, also variously expressed.

Frequently the constant term is left out altogether, especially in formulas pertaining directly to standard line constructions.

To clear up the situation the following deductions are made, and a discussion added to show when the approximate formulas can properly be used.

A and *B* in Fig. 1 represent a couple of parallel cylinders of radius r and distance between centres D. For convenience in reasoning it is assumed that they are made up of a large number of strands or elements.

A current I flowing through conductor A will set up magnetic fields inside of the conductor and in the surrounding space. Consider at first the flux inside of the conductor.

* PROCEEDINGS, A. I. E. E., September, 1907, p. 1409.

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The flux per unit length of line in section $d\,x_1$ is due to the current flowing inside of zone $d\,x_1$, which current is $\frac{x_1^2}{r^2}\,I$.

Thus the magnetomotive force per unit is $\dfrac{\frac{x_1^2}{r^2}\,I.}{2\,\pi\,x_1}$

The field intensity is $4\,\pi \times$ magnetomotive force $= \frac{2\,x_1\,I}{r^2}$

Therefore the flux $= \frac{2\,x_1\,I\,d\,x}{r^2}$

The electromotive force corresponding to this flux $= k \times$ flux in each section $= \int_0^r k \times \frac{2\,x_1\,I\,d\,x_1}{r^2} \times \frac{x_1^2}{r^2} = k\,\frac{I}{2}$. The equivalent flux corresponding to this electromotive force is $\frac{k\,I}{2k}$ $= \frac{I}{2}$, and therefore the equivalent inductance, which is $\frac{\text{flux}}{\text{current}} = \frac{1}{2}$.

The flux outside of the conductor is found in a similar way.

In that case the magnetomotive force per unit length is $\frac{I}{2\,\pi\,x}$ the field intensity $4\,\pi\,\frac{I}{2\,\pi\,x} = \frac{2\,I}{x}$ and the flux

$$M_0 = \int_r^{D-r} \frac{2\,I}{x}\,d\,x = 2\,I\,({}^{n}l\,g\;(D-r) - {}^{n}l\,g\,r) = 2\,I\,{}^{n}l\,g\,\frac{D-r}{r}$$

The total flux expressed in centimeter-gramme-second units is therefore $M = I\left(2\,{}^{n}l\,g\,\frac{D-r}{r} + \frac{1}{2}\right)$ and the inductance

$$L = \frac{M}{I} = 2\,{}^{n}l\,g\,\frac{D-r}{r} + \frac{1}{2}$$

Transforming this equation to practical units and expressing L in millihenrys per mile of conductor we get:

$$L = \frac{161}{10^3}\left(2\,{}^{n}l\,g\,\frac{D-r}{r} + \frac{1}{2}\right)$$

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In transmission lines D is usually large compared with r, so that the equation may be written:

$$L = \frac{161}{10^3}\left(2\,{}^{n}lg\,\frac{2D}{d} + \frac{1}{2}\right)$$

where D is the distance between centers of wires and d their diameter.

Determination of capacity between two parallel cylindrical conductors. Let A and B in Fig. 2 represent two conductors charged

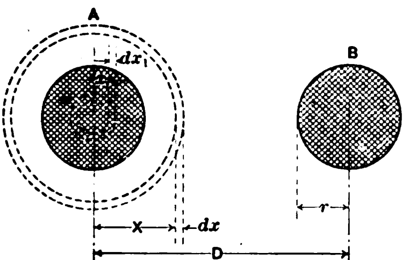

Fig. 1

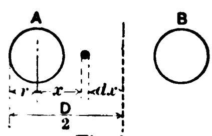

Fig. 2

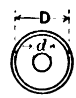

Fig. 3

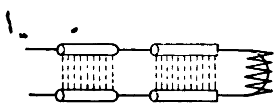
Fig. 4

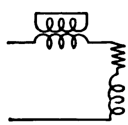
Fig. 5

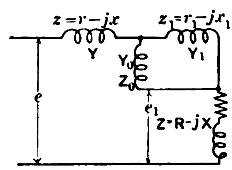

Fig. 6

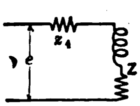

Fig. 7

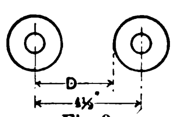

Fig. 8

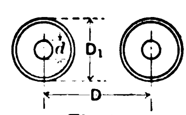

Fig. 9

with a certain amount of electricity Q, A being positive $+Q$ and B negative $-Q$.

Around each of these conductors is a field of stress, gradually decreasing towards zero potential plane.

The total field emanating from A is $4\pi Q$, thus the field intensity of an element at any distance x from A is $\frac{4\pi Q}{2\pi x}$ or $\frac{2Q}{x}$.

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The corresponding field intensity due to the charge in B is—
$\frac{4\pi Q}{2\pi (D-x)} = -\frac{2Q}{D-x}$, so that the resultant static field intensity or static potential is:

$$\frac{2Q}{x} - \frac{-2Q}{D-x} = 2Q\left(\frac{1}{x} + \frac{1}{D-x}\right)$$

Consequently, in moving the element from the plane of zero potential to the surface of the conductor its potential rises to $\int_r^{\frac{D}{2}} 2Q\,dx \left(\frac{1}{x} + \frac{1}{D-x}\right)$ which integrated is $2Q\,{}^{n}l\,g\,\frac{D-r}{r}$

The capacity, which is the ratio of charge to potential causing the charge, is therefore

$$C = \frac{Q}{2Q\,{}^{n}l\,g\,\frac{D-r}{r}} = \frac{1}{2\,{}^{n}l\,g\,\frac{D-r}{r}}$$

which in practical units is:

$$C = \frac{890\,k}{10^4\,{}^{n}l\,g\,2\,\frac{D-d}{d}}$$

where C is microfarads per mile of conductor

k specific inductive capacity,

D distance between centers of wires,

d their diameter.

In transmission lines where $K = 1$, and $2D$ is large compared with d, the formula can sufficiently accurately be written as:

$$C = \frac{890}{10^4\,{}^{n}l\,g\,\frac{2D}{d}}$$

Cables. With the present state of the art it would not be conservative to use a cable at more than 25,000 volts between conductors, although it is to be expected that at least with rubber-covered cables, or cables with insulation of gradually decreasing specific inductive capacity, a higher voltage can finally be used.

At present time essentially, or almost entirely, two kinds of cables are used, one having paper insulation and the other rubber insulation, both being covered with lead.

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Although the dielectric strength of paper is considerably less than that of rubber and therefore more insulation is needed due to the lesser cost, it is almost entirely used, and no doubt will remain so until cables for higher voltages are required.

It is almost impossible to give a general rule for the safe current capacity of a cable, since it depends largely upon what kind of conduit is used, the relative amount of insulation, etc. Perhaps 0.025 watts per square inch radiating surface (outside) is as fair approximation as can be made. When, however, the cable is laid directly in soil, 50% more current can be carried, and when placed in water 100% more current seems safe. This last case corresponding to 0.1 watt per square inch. The actual rise in temperature in the conductor is then about 30° cent.

On account of skin effect it is not desirable to use a conductor larger than about 1 in. in diameter in 60-cycle circuits, and one of 1.5 in. diameter in 25-cycle circuits, in which case the effective resistance is about 10% greater than the ohmic resistance. The fact that the conductor is made up of a number of small wires does not materially lessen the skin effect, since the individual strands are not thoroughly intermixed, but each remains at the same distance from the center at all times.

There is, however, for given outside diameter of the cable as compared with the outside diameter of the solid conductor, a slightly lesser skin effect in the case of the cable, due to the higher specific resistance of the cable, when considering the total cross-section.

In other words. there is less conductivity for a given area of cable than in the same area of solid conductor, and since the skin effect depends upon the resistance per given area the skin effect must be reduced. The theoretical equations governing this phenomena are extremely complicated and are therefore omitted.

The inductance and capacity equations deduced apply directly as long as all conductors belonging to the same circuit are in the same conduit or cable. If, however, that is not the case, but as in a single-conductor cable independent cables are used for the outgoing and incoming conductors "effective" values have to be calculated.

In the preceding were given the inductance and capacity formula for two parallel cylindrical conductors. In dealing with cables we require to consider the inductance and capacity between concentric conductors, such as single conductor in lead-

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covered cable where current is permitted to flow in the lead or concentric conductors in general. In that case the equations become

$$L_{mh} = \frac{370}{10^3} \, {}^{10}\log \frac{D}{d}$$

$$C_{mf} = \frac{770\, k}{10^4 \, {}^{10}\log \frac{D}{d}}$$

Where L and C are respectively inductance in millihenrys and capacity in microfarads per mile of conductor. Thus in a concentric single-phase cable in 0.5 mile of length of cable or in a three-phase cable in 1 mile of length.

Effect of grounded lead covering of single-conductor cables. The lead covering obviously acts as a short-circuited secondary to the electromotive force induced by the reactance of the line. It consumes some of the electromotive force, therefore reduces the inductive drop but increases the ohmic loss due to the currents in the lead.

In calculating the phenomenon we will substitute for the line the primary of a transformer of same resistance as the line and with a magnetizing current the same as the line current at the voltage corresponding to the reactance electromotive force.

The reactance of the primary in this equivalent transformer is caused by the flux between lead covering and the conductor and is therefore as a rule quite small.

The secondary resistance corresponds to the resistance of the lead (which for given cross section is 14 times that of copper). the reactance is the same as that of the primary.

We can therefore diagramatically show these circuits as in Fig. 4.

The lead covering being grounded acts as a sheet of metal surrounding the conductor in inductive relation to the primary.

Or as in Fig. 5, where the line resistance and reactance are assumed as concentrated in a transformer.

Or finally as in Fig. 6, as a combination of inductive circuits with the proper transformer constants.

Let e = line voltage.
$Z = R - j\,X$ = load impedance.
$z = r - j\,x$ = primary impedance.

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where r = line resistance.

x = reactance between conductor and lead.

$z_1 = r_1 - j\,x_1$ = secondary impedance.

where r_1 = resistance of lead covering (For the same cross-section 14 times that of copper.)

Y_0 = primary admittance = $j\,b$ where

$$b \text{ is } \frac{I}{E_x} = \frac{1}{x_0} \text{ or } Y_0 = \frac{j}{x_0}$$

x_0 = line reactance if no lead covering existed and a conductor of the same outside diameter as that of the lead covering were used in the calculations.

$$z_0 = \frac{1}{Y^0} = -\frac{j}{b} = -j\,x_0$$

Joint admittance of the two parallel circuits of impedance z_0 and z_1 is $Y_0 + Y_1 = Y_2$. The corresponding impedance z_2 =

$$\frac{1}{Y_0 + Y_1} = \frac{1}{\frac{j}{x_0} + \frac{1}{r_1}} \text{ since } x_1 \text{ is small}$$

$$\text{we have } z_2 = \frac{r_1\,x_0}{j\,r_1 + x_0} = \frac{r_1\,x_0\,(x_0 - j\,r_1)}{r_1^2 + x_0^2}$$

Total impedance is $= z_2 + z + Z$

Current therefore $= \dfrac{e}{z_2 + z + Z}$

Voltage across load $e_1 = \dfrac{e\,Z}{z_2 + z + Z}$

$$E_1{}^1 = \text{drop in line } e - \frac{e\,Z}{z_2 + z + Z} = \frac{e\,(z + z_2)}{Z + z + z_2}$$

Let $z + z_2 = z_3$

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We have then $E_1^1 = \dfrac{e\, z_3}{Z + z_3}$ ....A

In an ordinary line we have

current $= \dfrac{e}{Z + z_4}$. Drop in line $E_1^1 = \dfrac{e\, z_4}{Z + z_4}$ ..B.

Comparing these two equations, A and B, we see that if the values of line impedance obtained by writing $z_4 = z_3$ are inserted we can use the ordinary line equations

$$Z_4 = r_4 - j\, x_4.$$

From above we have—

$$Z_4 = z_3 = z + z_2 = r + \frac{r_1\, x_0^2}{r_1^2 + x_0^2} - j\left(x + \frac{r_1^2\, x_0}{r_1^2 + x_0^2}\right)$$

or neglecting x, which is small, we can write the effective resistance as—$r + \dfrac{r_1\, x_0^2}{r_1^2 + x_0^2}$

and the effective reactance $= \dfrac{r_1^2\, x_0}{r_1^2 + x_0^2}$

As a rule x_0 is small compared with r_1 and we can write

$$\text{effective resistance} = r + \frac{x_0^2}{r_1}$$

$$\text{" reactance} = x_0$$

When estimating the reactance and effective resistance of a grounded single-conductor lead-covered cable—calculate the ohmic resistance r of the conductor, the ohmic resistance r_1 of the lead covering, (specific resistance 14 times that of copper) determine the reactance x_0 as between two parallel conductors of same diameter as the outside diameter of the lead, and substitute the values so obtained in the equations given above.

Instance. Two cables of 1000 ft. total length placed on 4.5 in. center, each cable contains a 0000 B. & S. conductor. Outside diameter of lead 1 in., inside diameter 0.75 in. What is the effective resistance and reactance of 25 and 60 cycles?

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$r = 0.049$, area of lead $\frac{1}{8}\pi\frac{7}{8} = 0.343$ sq. in. corresponding to cop-

per section $= \dfrac{0.343}{14} = 0.0245$ sq. in.

Therefore $r_1 = 0.332$.

At 25 cycles reactance outside of lead is $\frac{2\pi 25}{10^3} \times \frac{161}{10^3}$

$$\left(2\,{}^n l\,g\frac{8}{1}+\frac{1}{2}\right)\frac{1}{5.28} = 0.0223 \text{ ohms.}$$

Therefore effective resistance

$$= 0.049 + \frac{0.0223^2}{0.332} = 0.0505 \text{ ohms.}$$

At 60 cycles the reactance is 0.0535.

Therefore effective resistance = 0.0572.

The resistance is increased 3% in the first case, 16% in the latter.

To illustrate the increased loss in a single conductor lead-covered cable, table *A* has been prepared. It applies to a single-conductor cable No. 0000 B. & S. having a lead covering $\frac{1}{16}$ in. thick, the outside diameter of the lead covering is 1 in. Losses are given for various distances to return conductor and at various frequencies.

It shows that in general the losses introduced are small and need only be considered in 60-cycle systems when the cables are a considerable distance apart. This table refers to one mile of conductor.

Cycles			12.5	
Distance inches	2.13	4	12	24
r	0.264	0.264	0.264	0.264
$x_0 = x_e$	0.0249	0.0458	0.0772	0.0952
x_2^0	0.0006	0.0021	0.0059	0.009
r_e	0.2642	0.2649	0.2665	0.2678
Increase	0.1%	0.34%	0.98%	1.4%

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Cycles		25		
Distance inches	2.13	4	12	24
r	0.264	0.264	0.264	0.264
$x_0 = x_e$	0.0497	0.0916	0.1544	0.1904
x_0^2	0.0025	0.0084	0.0238	0.0362
r_e	0.2651	0.2676	0.2743	0.2796
Increase	0.42%	1.37%	3.9%	5.9%

Cycles		60		
Distance inches	2.13	4	12	24
r	0.264	0.264	0.264	0.264
$x_0 = x_e$	0.1193	0.220	0.3706	0.4570
x_0^2	0.0142	0.048	0.137	0.208
r_e	0.2701	0.2848	0.3233	0.3536
Increase	2.3%	7.9%	22.5%	33.9%

Effect of a non-grounded lead covering in single-conductor lead cable. Since there is a difference in flux between the inside and the outside half of the lead covering, currents must flow alongside the covering in one direction in the inside half, in the other direction in the outside half.

The average distance between center of one conductor and the nearer half of the lead covering of the other conductor is

$$D - \frac{D_1}{4}$$

The average distance to the outer half is

$$= D + \frac{D_1}{4}$$

The difference in inductance is therefore

$$l_d = \frac{742}{10^3}\left({}^{10}\log \frac{D + \frac{D_1}{4}}{d} - {}^{10}\log \frac{D - \frac{D_1}{4}}{d} \right)$$

$$= \frac{742}{10^3}\ {}^{10}\log \frac{D + \frac{D_1}{4}}{D - \frac{D_1}{4}}$$

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Where l_d is expressed in millihenrys per mile of conductor.

With I current flowing in the conductor and the resistance of the lead covering calculated as above, that is a conductor of same length, as the conductor proper, and with the actual cross-section of the lead, we get:

$$\text{Reactance electromotive force} = \frac{2\,\pi\,n\,l_d\,I}{10^3}$$

$$\text{and eddy currents in lead} = \frac{2\,\pi\,n\,l_d\,I}{4\,r_1\,10^3}$$

$$\text{Thus the loss in the lead} = \frac{4\,\pi^2\,n^2\,l_d^2\,I^2}{4\,r_1\,10^6}$$

Therefore the effective resistance

$$= r + \frac{n^2\,l_d^2}{r_1\,10^5}$$

Where n = frequency

l_d = inductance in milhenrys

r_1 = lead resistance—as defined above.

r = resistance of conductor proper.

With 4 in. distance between centers and one inch conductor, we get:

$$D + \frac{D_1}{4} = 4.25$$

$$D - \frac{D^1}{4} = 3.75$$

$$l_d = \frac{742}{10^3}\ {}^{10}\log 1.13 = \frac{40}{10^3}\ \text{mh.}$$

Therefore effective resistance

$$= 0.049 + \frac{25^2 \times 40^2}{0.33 \times 10^6 \times 10^5} = 0.04903.$$

We see from this that the eddies in a single conductor lead covered cable are negligible if the lead is not grounded.

Effect of iron-armored single-conductor cable. If the cable instead of being covered with lead, were covered with a magnetic mater-

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ial such as iron, the problem would be more complicated on account of the increased flux due to the iron. Such conduit is indeed quite out of the question on account of the increased reactance and eddy losses.

From the saturation curve of the iron it is possible to determine the magnetic density and therefrom the flux in the iron for a given current in the conductor.

Assume this flux to be M

E, the electromotive force corresponding to this flux is

$$\frac{4.44 \times M \times n}{10^8}$$

The corresponding reactance is $\frac{E}{I}$

which reactance should be added to the normal reactance as obtained in a non-magnetic system.

The hysteresis loss corresponding to this density is found from the hysteresis curves of the iron, and this loss divided by I^2 gives an equivalent resistance which should be added to the resistance as obtained in case of a non-magnetic conduit.

As an instance. Assume the cable described above covered by iron instead of lead, and that 150 amperes are flowing in the main conductor.

Assume further that the iron is $\frac{1}{8}$ in. thick and that the total loss due to eddies and hysteresis is five times as great as the hysteresis loss proper.

The magnetomotive force available is $150\sqrt{2} = 212$ ampere-turns.

The magnetic length is $\frac{7}{8}\pi = 2.75$

$$\text{Magnetomotive force per inch} = \frac{212}{2.75} = 77$$

This corresponds to a density of 100,000 lines per sq. in.

The magnetic cross-section $= 1000 \times 12 \times \frac{1}{8} = 1500$ sq. in.

Therefore the total flux $M = 150{,}000{,}000$ and $E = 166$ volts, the reactance due to iron is thus $\frac{166}{150} = 1.1$ ohm.

From hysteresis curve we find the loss per cubic inch per cycle $= 0.028$ watts.

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Therefore the loss is $0.028 \times 5 \times 1500 \times \frac{7}{8} \times \pi \times 25 = 14{,}500$ watts.

Whereas the $I^2 R$ proper is but $150^2 \times 0.049 = 1100$ watts.

It can readily be proved that even the thinnest iron covering is prohibitive in single-conductor cables for alternating currents.

In concluding the discussion of the effect of armor we may add that where two or more conductors involving a complete circuit are carried in the same conduit, it matters not whether the covering is of iron or lead, grounded or not grounded. The effect of the covering on the resistance or the reactance is negligible.

Iron wire and cables used as electrical conductors. Since the ohmic resistance and permeability of iron changes very considerably in different grades and since the permeability varies with the current, it is evident that it is very difficult to lay down any definite rules regarding the effective resistance and reactance. So that in order to get accurate determinations it is necessary to test samples of the conductor intended to be used.

With the present price of copper wire, it is evident however that wherever small power is carried relatively short distances at high voltages, iron wire, or at least iron cables, could be used, and calculations must be made before the actual wire has been secured.

With direct current the matter is fairly simple, since the permeability does not enter and wires of definite resistance could be ordered. This resistance in iron wire varies from say four times that of copper to seven or eight times that of copper.

With alternating current the skin effect causes additional resistance, which, at least in large conductors, is considerable, often several times that of the true ohmic resistance. This effect is however small in small wires, say wires of number 8 to 12 B. & S. gauge, but with large wires it is considerable. Such small wires can not, however, well be used for transmission lines for mechanical reasons. Therefore, it seems probable that stranded cables only need to be considered.

From a number of deductions it would seem as if the effective resistance of such stranded cable (7-strand cable) could be expressed by the following formula:

$$R = r + \frac{K\ N\ B^2\ D^2}{r\ 10^5}$$

In which K depends upon the permeability and may average 2.

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R = effective resistance per mile of cable.
r = ohmic resistance.
N = frequency.
B = current density in amperes per square inch superficial area.
D = external diameter of the cable.

The reactance can be approximated as:

$$X = x + 0.01\,N + \frac{K\,N\,B^2\,D^2}{r\,x\,10^5}$$

Where X = effective reactance per mile of wire.
x = reactance as obtained if the cable were made of copper.

These formulas apply fairly well, at least to cables of from ¼ in. to ½ in. external diameter. It is unlikely that larger cables will be used, since the skin effect is very considerable with ½ in. cables, and it is unlikely that smaller cables will be used, on account of mechanical reasons.

It is to be noted in connection with these formulas that the reactance as a rule is not prohibitive with the use of iron cables. It has often been thought that the reactance was the limiting feature, but this is not the case—the effective resistance is of more importance.

When using very large iron or steel conductors, such as rails in the case of single-phase railroading, the effective resistance can be estimated from the degree of penetration of current, and this has been approximated by Steinmetz and others to be

$$\delta = \frac{2000}{\sqrt{g\,\mu\,N}}$$

Where δ, the penetration, is expressed in inches.

g = electrical conductivity, which with soft iron is about 110,000, μ is the permeability and might be about 500 and N is the frequency.

Consequently, the resistance of such large iron and steel conductors does not depend upon the actual cross-section, but upon the perimeter. It is furthermore proportional to the square root of the frequency.

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Discussion on "Light from Gaseous Conductors Within Glass Tubes—The Moore Light," at New York April 26, 1907

(Subject to final revision for the Transactions.)

Gano Dunn: While we are waiting for the remainder of the tests which are to be made upon the tube and the lamps strung around the room, we may as well proceed with the discussion. I feel that we have been listening to the exposition of a new art. My mind goes back to 1893, 1896, and also to 1898, the time of the "Moore Chapel," when the Institute heard from Mr. Moore before. In those days what he had to show compares with what he shows us this evening as Stevenson's original "Rocket" compares with the modern Atlantic type of locomotive. Two years ago on entering the Madison Square Garden, I was greatly impressed with the appearance of a Moore tube in the lobby, and admitted then that I made a mistake in considering the Moore system not a success. I had had the impression that it was good only for illuminated signs and relatively unimportant work. The Madison Square Garden tube was a revelation.

We should be careful not to estimate the value of the Moore system solely by its efficiency. There are radical differences in the character of its distribution, its color, and its method of operation, from any one of which important advantages may spring. For instance, on account of its longitudinal source, the intensity of the Moore light does not vary inversely with the square of the distance, and from this follows freedom from shadows and a certain similarity to daylight.

The effectiveness of a luminous source should not be measured by how much light it emits, but rather by how much light it delivers where the light is wanted. A lamp of high intrinsic brilliancy, that is, of concentrated source, over-illuminates surfaces near it, while it under-illuminates surfaces somewhat removed from it. To the under-illuminated surface full credit is not given for such illumination as exists, because the eye usually rests upon this surface after having rested upon a brighter surface or possibly upon the lamp itself. There has to be an excess of light on surfaces near the lamp in order to bring surfaces away from the lamp up to the desired minimum of illumination. The excess illumination being unnecessary, is wasted. Worse than this, having fatigued the eye, it renders less evident the illumination that does actually exist upon the under-illuminated surface. The largely distributed source (a tube many feet in length) is what I had in mind when referring to lighting by Moore tubes as a new art. Other sources of light are not larger in volume than a nutshell.

We must be ready to see disadvantages in Moore's system as well as advantages, and I hope both will be clearly brought out in the discussion.

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C. P. Steinmetz: The second part of this paper is extremely interesting, and I believe is a valuable addition to the literature of producing light by what may be called an improved Geissler tube. It is the old Geissler tube in the form of a commercial illuminant. If we look back on the history of Mr. Moore's work, we find that originally he produced a varying-in-pressure-contact, some kind of a flimsy device in a vacuum, and then proceeded to operate Geissler tubes at extremely high frequency, using motor-generator sets. Here at last we find the light at commercial frequencies, and in a commercial installation, taking its place as one of the commercial illuminants.

The paper gives the first actual engineering data of this kind of light, the energy, volts, and amperes, and some data on efficiency, etc. The author gives comparative data on the illumination produced by the Moore tube and the incandescent lamp. Later on, comparisons are made between the arc lamp and other systems. I am not impressed with the comparative values given, except that they show that incandescent lamps and arc lamps can be installed in such a manner as to get very little light from very much power. That fact was known long ago, without having special tests made. If the installation of the incandescent lamp is left to the artistic sense of an architect, or to mere accident, such a condition will obtain, but the comparison is not fair. If an unsatisfactory incandescent light system, unsatisfactory by reason of poor installation, poor type of reflector, etc., is replaced by an intelligently installed system, the advantages of the latter will be apparent. I have no doubt that if Mr. Moore's hopes are fulfilled, and in future all the plumbing establishments in cities and villages and country towns have a department of glass plumbing, and if a future illuminating engineer goes around in the country towns or villages, he can use the old 3.1 watt incandescent lamp and replace very many Moore tubes installed by the local plumber and show a vast improvement in efficiency by intelligently installing with proper reflectors, the old incandescent lamp. That does not mean anything: it only means that if the old installation of incandescent lamps was made by an illuminating engineer, he should have his license withdrawn, if such a thing existed.

Some illuminating efficiency measurements are expressed in terms of in hefner-feet. I regret the use of the word hefner here. In the United States illumination is measured in British candles, not in hefner candles. The hefner candle is 0.88 times the British candle, so that the values given in the paper have to be multiplied by 0.88 to bring them to the American standard of illumination. Mr. Moore finds an illuminating efficiency, mean hefner-foot per watt, of 2.15. One British candle as a source of light of one mean spherical candle-power gives an illumination of one candle-foot at one foot distance. One mean spherical candle-power then gives 4π candle-feet, or

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12.56 candle-feet, dividing this by 0.88 to reduce it to hefner-feet, gives 14.28 hefner-feet per mean spherical candle-power. Mr. Moore gets 2.15 mean hefner-feet per watt; reduced to mean spherical candle-power, this means that his light consumes in the useful illumination 6.64 watts per mean spherical candle-power, if one counts only the light which reaches the illuminated plane. It means, then, that a very considerable part of the light is thrown away, absorbed by the walls, ceilings, etc. I do not believe it is an unfair estimate, for such a class of light, to say that 50% of the light is wasted. That is estimating that half the flux or light radiated by the tube reaches the plane of test. That would give an efficiency of 3.72 watts per candle.

It is instructive to apply this to the last column headed "Incandescent system," and that will bear out what I stated, as to what should be done to the illuminating engineer who installed these incandescent lamps, which show but 0.39 hefner-feet per watt.

Assuming 4 watts per mean spherical candle-power, which is a reasonable value, one should get, for all the useful light in the illuminated plane, 3.57 hefner-feet per watt, or eight times as much as is given here. It follows that if these were four-watt incandescent lamps they would lose seven-eights of the light before the light reached the illuminated plane. This explains the enormous difference in illumination by these two sources.

The values given in comparing the Moore tube with the arc lamp system, allowing for the Moore light half of the light wasted before it reaches the illuminated plane, indicate an efficiency of 2.56 watts per mean spherical candle-power, and 14.8 watts per mean spherical candle-power of the flux of light sent by the arc lamps on to the illuminated plane, a ridiculous value. It seems probable that the arc lamps were hung without reflectors or diffusers anywhere on the ceiling.

In the photometric tests the most efficient tube gives 1.4 watts per hefner-foot. That means at right angles to the tube. The light in the equator of a linear source is $\frac{2}{\pi}$ the average or mean spherical. Dividing by 0.88, to reduce to our standard of light, the British candle, gives 2.5 watts per mean spherical candle-power or per lumen, that is, per unit flux of light. The test of the illumination measurements gave 2.56, and probably this is about the efficiency of light production of the Moore tube.

Leaving out all illuminating questions, and merely considering the matter of the flux of light per watt, the next point to consider, then, would be the distribution of the light. But the first and important question always is how much light is got from the source of light? The best efficiency of the Moore tube seems to be about 2.5 watts per unit flux of light, that is, per lumen. This gives about the same efficiency of the tantalum lamp, or not very far from the enclosed arc; it is better than the carbon filament incandescent lamp, but inferior to the tungsten lamp.

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The carbon dioxide tube is recognized as less efficient, and I do not need to refer to it. I desire here, however, to draw attention to the fact that the efficiency of the Moore tube has arrived at that stage where it is now in the range of commercially practical efficiencies as an illuminant. It is not any more an inefficient illuminant, although it naturally is not of the same class in efficiency as the mercury-arc lamp.

Efficiency of light production is, however, not the only thing to consider. The essential question is to make use of the light, and that leads to the question of distribution. A useful feature is the low intrinsic brilliancy which eliminates the dazzling and blinding glare, with this new source of light, while the tungsten filament, for instance, is rather bad in this respect. However, too much importance must not be attributed to this feature, because even a point source of light can be diffused by diffraction or diffusion, a holophane or frosted globe. Light is lost by this procedure, but if five hefners per square inch is considered as a proper low intrinsic brilliancy, a 32-c-p. tungsten lamp enclosed in a frosted globe three to four inches in diameter brings the intrinsic brilliancy of the whole globe down to five hefners per square inch, probably less, with from 15 to 20 % loss of efficiency, and still leaves an efficiency far higher than that of the Moore light. You can allow in favor of the low intrinsic brilliancy from 15 to 20% lesser efficiency, but not more, because you can get low intrinsic brilliancy by diffraction with this loss.

The last part of the paper is a rather voluminous discussion of illuminating engineering matters, which would be very essentially improved by greatly shortening it, and would then have more value by making it more probable that the busy engineer would read through it, and there are some features in it which are well worth reading, but they are buried among so many pages that life, as a rule, is too short to afford time to go through it. I read it, however.

The author refers to the blinding brilliancy of the mercury tube. I have never noticed that. I am using the mercury tube exclusively as an artificial illuminant for any work that I may have to do. I would not think of using any other source of artificial light and find it by far the best. Further, the author says:

> The only commercial and proper method of comparing all sources of light is on the basis of their ability to produce useful illumination, and not by any other basis.

I should challenge that. This is the ultimate purpose, and the customer who makes a contract to light his premises with an economical amount of power specifies this; but to the illuminating engineer who takes the contract to put in the lights, the important question is what type of light to employ, so as to use the least amount of power to produce the best illumination. For the illuminating engineer the most important question is what

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source of light gives the maximum flux of light for a given amount of energy, the maximum quantity of light per watt. The next question is, whether this source of light is suitable for direct distribution, or how much of the light may have to be wasted so as to get the proper distribution. The statement quoted above rather begs the whole question of illuminating engineering.

The statement is made that photometric tests do not amount to anything. That is an old statement, and has been repeated very often, but I do not think that anyone will accept the dictum that the mean spherical candle-power does not mean anything. While with a light source of this kind one cannot speak of mean spherical candle-power, one can speak of the total flux of light; and it does mean something to determine how much total flux of light can be got per watt; indeed, as stated above, it is the most important question in the matter of artificial illumination.

So we must know how many lumens per watt we get, and since the lumen is the total flux of light which one candle-power gives, it is a convenient substitute to speak of mean spherical candle-power; but when we speak of mean spherical candle-power with a linear source of light, as the mercury lamp or the Moore tube, the mean spherical candle-power means the unit of flux of light, or the lumen, and that is independent of the shape of the source of light.

In regard to the proposed method of comparing lights, by lighting a room 40 by 80 feet, for instance, in lighting my house this would not help me much, because my house has no room quite so large. Light is used not only to illuminate stores and halls but a great deal is used for other purposes. However, if illuminants are to be tested in a 40-by 80-ft, room, to find out which illuminant requires the least energy to give a certain illumination in such area, there would be found, first, the mercury lamp, then a long interval; then the tungsten lamp, and another long interval; and then the Moore light, the tantalum lamp, and the enclosed arc, and finally the different other metal-filament incandescent lamps and carbon lamps and Nernst lamps, etc. So after all, neither the Moore light, nor any incandescent light, has the same degree of efficiency as the mercury lamp.

While criticising the character of the paper, especially the first and third parts, one must not forget that the second part contains some very valuable and important information. Mr. Moore is to be congratulated on the great advances he has made in the last few years, in reaching commercial conditions with his light, commercial frequencies, commercial voltages.

There are some things which have not been especially dwelled on, among them the remarkably ingenious valve arrangement of feeding air or gases into the tube and maintaining a constant vacuum. We must remember that the vacuum in this tube is about $\frac{1}{8000}$ of atmospheric pressure. To maintain constant such

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a low pressure, not visible any more in a mercury gauge, and maintain that constant within a few per cent. is a very remarkable achievement. So while criticising a part of the paper, I do not want to convey the impression that I do not admire the work which has been done by Mr. Moore. . I recognize that he has made enormous steps in advance since we last heard from him. I also very much appreciate the very ingenious way of feeding these gases into the tubes, and the method of getting rid of the oxygen in the air, and feeding nitrogen or carbon dioxide. These are remarkable and ingenious devices which can only be admired.

Percy H. Thomas: Mr. Moore, has, I believe, given us a very timely and generally satisfactory paper. In addition to the general information about and description of his actual apparatus, he has called attention to a number of valuable points. For example, a great many people do not realize the value of lighting a room from one outlet and doing away with the pendants and fixtures and small outlets. Not only is a great deal of expense saved, but a good deal of fire-risk as well. The elimination of the cost of multiple outlets and many units, fuses, cords, etc. is one of his largest factors of economy over incandescent lamps. This is an advantage that his system of lighting shares in some degree with the Cooper-Hewitt light.

Mr. Moore has always maintained, and very emphatically, that his tube produces artificial daylight, and he apparently expects us to assume that there is no difference between the Moore light and daylight. This statement should be challenged. In the first place daylight gives practically a continuous spectrum. Mr. Moore's light comes from gases and must be a banded spectrum, a few colors well distributed over the spectrum, it is true, but still unable to give the same effect as a true continuous spectrum. How much practical importance this deficiency will be found to have can only be determined when a sufficient number of commercial installations have had considerably extended use.

In the second place, the tube does not give a strictly perfect diffusion, though at first sight it may seem that this is the fact. Illuminated surfaces are plain surfaces and have two dimensions, but the Moore tube has only one dimension, so to speak. The diffusion is perfect in one direction and very imperfect in the other direction. Place a pencil between a piece of paper and the light, with the pencil parallel to the tube, and there results a relatively dense shadow. Place the pencil crosswise and there will be no shadow at all. This shows the failure to diffuse across the tube.

It is even possible with incandescent lamps distributed over the ceiling to get a more perfect diffusion than with the Moore tube. The discontinuity added by the use of incandescent units in the direction of the length of the tube is not as important in disturbing uniform distribution as the large gaps between

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the tubes in the other direction. Dr. Pupin with his "load-coils", which he used in telephone circuits, found that a few, perhaps seven or eight coils per wave length, had nearly the same effect as distributed inductance and capacity.

Furthermore, I cannot agree that daylight necessarily produces the best spectrum. This a matter purely of experiment and experience. If the eliminating of the red or the violet from daylight is found to make an improved light to work by for any particular purpose, it is then better to suppress the red or the violet rays. I believe for many purposes that this suppression is advantageous.

There are a few more statements that perhaps require challenging. Mr. Moore says:

> It is now impossible to state definitely what their final life will be, beyond the general statement that some of these tubes have already been in operation over 4000 hours without change, and that there are good reasons for believing that they should continue to run at least as long again, which is a much longer life than any other form of illuminant yet invented.

If he will take pains to inquire, he can find out a great many places where commercial tubes of the Cooper-Hewitt type have operated for 10,000 hours; in this I am speaking of commercial installations.

He also says:

> It is the blinding brilliancy of the mercury tube that makes even a direct glance at it so very harmful to the eye.

I wish to state here that this statement, the equivalent of stating that the mercury vapor lamp is very harmful to the eye, is diametrically opposed to my own experience with this type of lamp.

Mr. Moore disposes very summarily of the new types of incandescent lamps, but perhaps they can take care of themselves.

In regard to Fig. 8 of the paper, Mr. Moore has taken a number of stations at different points in a room and determined the intensity of illumination at each, and then averaged the results. These points are well chosen to determine the intensity of the illumination at different locations, but it is not fair to average these values as they are taken, to get the average illumination, because some of them represent a very much smaller area than others. The proper way to obtain such an average is to divide the surface into a number of equal units, determine the illumination of each unit, and average these.

Though Mr. Moore's mercury valve for supplying gas regularly is very ingenious, yet I question its reliability if the lamp is left unused for a considerable time. Mercury-sealed valves while practically tight for a short time are not usually so indefinitely; after a while the mercury absorbs a little air on the surface exposed to the atmosphere and delivers it by diffusion on the vacuum surface. Once the tube leaks sufficient air, by being out of commission for a month's time perhaps, it would not start up again.

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Some difficulties, I imagine, will be found; for example, the great inconvenience of a failure. This room, for instance, is entirely dependent on each particular part of the tube; any crack or damage done to the tube in any part will put the room in darkness. Furthermore, repair is not a matter of taking a spare tube out of the closet and putting it up. Dependance must be placed upon the manufacturer. The organization of a well-disciplined "trouble force" can eliminate some of the trouble, but in many cases it will be found a serious handicap. The power-factor seems to be a variable question. If the power-factor is made very high it means the elimination to that extent of the resistance or inductance backing which absorbs voltage, and will allow more variation in the current which might become a serious factor. Where power is bought from a lighting company and paid for by meter, a low power-factor is not serious because only the drop in the wiring needs consideration; but for those who do their own lighting the capacity of the generator must be considerably greater for a low power-factor load to get a given quantity of energy than with the high power-factor. This will be an added charge against the Moore tube in cases where the power is used largely for supplying these tubes.

With the whole illumination dependent on one or two or three outfits, it is impossible to light a small portion of a room only. In a factory two men who are working in a corner cannot light that corner only, but must perhaps use ten or twenty times as much energy as otherwise would be required. This objection cannot be urged against the Moore tube in all places; it simply shows a certain limitation when the broad field is considered.

Summarizing: it is a little too soon to tell what the commercial field of the Moore tube will be; undoubtedly there is a field for such a light.

Its good points are its relatively high efficiency (not the best, but relatively good—probably better than most carbon incandescent lamps), its even diffusion, and the fact that it has no bright spots and requires very few outlets.

Clayton H. Sharp: I think we all greatly admire the persistency of purpose and the courage with which Mr. Moore has tackled and has kept tackling for ten or fifteen years this great problem of the production of artificial light by the incandescence or luminescence of gases. Certainly the goal toward which he was striving, and the end which he sought to reach, was a most tempting one. We have all heard a great deal about the low efficiency of all of our ordinary illuminants; very few of them approach five per cent. luminous efficiency. Some of them may reach the value of 10% possibly, but most of them are perhaps of only two or three per cent. luminous efficiency. It certainly is a very attractive problem, that of producing an illuminant working at a luminous efficiency of 90% instead of 5%. I think we all regret sincerely that, judging by present

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indications, in his endeavor to reach this worthy goal Mr. Moore has failed. He has, however, succeeded in producing a practical illuminant which will undoubtedly find a field for itself in certain applications and which has an efficiency that brings it on a par with many of the other illuminants of the present day.

Mr. Moore says that the watts per hefner of the yellow tube vary from 1.3 to 2.5 watts per hefner-candle; or, in other words, from 1.5 to 2.9 watts per candle measured at right angles to the tube. The white tube, the carbon dioxide tube, has a lower efficiency, but no data are given on the watts per candle of the white tube. However, we may arrive at a value by comparing the conclusions drawn from two of the illumination tables which Mr. Moore gives: we find in this way that the white efficiency bears a ratio to the yellow efficiency of 1.5 to 2.9, or about 1 to 2. In other words, the yellow tube is about twice as efficient as the white tube. I do not think we can lay much weight on these comparisons, since, as Mr. Moore himself has stated, all comparisons of illuminants made by taking illumination values under certain specific conditions, are practically valueless as general criteria for the illuminants themselves. However, taking this comparison, we find that the watts per candle of the white tube would range from 3 to 3.8. The yellow tube, according to this, shows an increase in efficiency over the carbon-filament lamp, but this increase is by no means revolutionary. On the other hand, its efficiency, according to these data, is considerably less than that of the tungsten lamp. Consequently we can say in a general way that the Moore light does not represent an essential gain as compared with the other illuminants at the present time. If, therefore, it is to find a place as a practical illuminant, it must show certain other advantages which the illuminants with which it competes do not possess.

What are some of the advantages? It gives a diffused light, that is perfectly true; it is a light of low intrinsic brilliancy, it has no bright spots to blind the eye; it does away with a certain amount of wiring in the building. What are some of the disadvantages. I think some of us might say that the color of it is not all that it should be; it may be the color of daylight, but it is a peculiar kind of daylight; it has the great disadvantage of not being divisible, we throw a switch and turn on all the light into a room; we cannot have a little light here or there, as we need it. This point was brought out by Mr. Thomas. This indivisibility of the Moore light makes it necessary, it seems to me, in all or nearly all of the installations where it is used, to supplement it by some other system of lighting which has the feature of divisibility. It would hardly do, it seems to me, to place all the reliance for the lighting of a room of any importance whatever on a tube of this kind, for we know something about the fragility of glass. I do not think that we can consider the tube to be absolutely immune from breakage, and if it breaks we are in the sad position of being obliged to call in, not the

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ordinary plumber, but the glass plumber. The glass plumber may be available if we have our installation within a proper distance from the factory, but this feature would be a very disadvantageous one in any installation which is at a distance from these special glass-plumbing facilities.

Another serious disadvantage, noticed here to-night, is the flickering due to the alternating current. This is an exclusively alternating-current lamp at the present time, and when it is used on alternating current of a commercial frequency, such as this, we notice a very marked flickering on objects moved quickly in the light. In cases where the objects have to be handled with rapidity this would be a serious practical disadvantage. In any room where the objects are moved rapidly the effect produced could be scarcely called anything less than weird; unless it is possible to overcome this disadvantage in some practical way, and it is hard to see how this is possible, we must mark this down as a serious detriment to this style of lighting.

Another result of the indivisibility of the lighting is its inapplicability to localized lighting. Diffused and distributed lighting such as we have in this hall is excellent for many purposes, but we do not want it for all purposes. Where localized lighting is desired rather than distributed lighting; the economical illumination of certain portions of a room rather than uniform illumination of the whole room; we must use something which is capable of division, and the Moore tube would appear to be ruled out in such cases.

Let me say one word regarding illuminometer comparisons of various illuminants. This method is undoubtedly excellent for many purposes. If we have a certain room that we wish to illuminate, and if we could carry out illuminometer tests with the various kinds of lighting appliances that are available, we could determine the best system for lighting that room, but unfortunately research of this kind is something which cannot be carried out except under very special conditions. Ordinarily the matter of illuminating a certain space has to be given into the hands of an illuminating engineer who must work with such data as are available, and from the results of experience he has had in similar installations, to choose the kind of illuminant he considers best for the purpose and install it to the best advantage he knows how. As Mr. Moore said, comparisons of illuminations made under certain specific conditions are generally worthless for the purpose of generalization. We need to be able to generalize. We should know how much light a certain source will emit with a given amount of energy. In order to do this we have to study the source itself and determine its total flux of light per watt. This does not mean a test of the illumination in a certain specified room, 40 by 80 feet, but a study of the source of light itself. Without wishing to depreciate the value

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of illumination tests—for illumination tests I thoroughly believe in—I do not think we could accept the general validity of results that would be obtained under certain specific conditions, in showing the availability or non-availability of all sources of light. In that connection I wish also to raise my voice in deprecation of the term "watts per hefner" and "hefner-foot". It is bad enough to have the "candle-foot", because the candle-foot ought to mean the product of the candle-power by the feet, but it does not mean that. When we lug in an extraneous unit of light which is represented by a most excellent standard of light; namely, the Hefner Alteneck amyl acetate lamp, but which is not practically recognized as a unit in this country, we are going far astray and getting badly mixed up in our units of measurements. If Mr. Moore had used the hefner-metre in measuring the illumination I should have less quarrel with him because the metre and the hefner go together. The hefner knows nothing about the foot, and the foot does not know much about the hefner.

Another statement should be challenged, and that is that the average watts per candle of incandescent lights used in the city of New York is in the neighborhood of five. By a comparison such as one can make from a casual investigation of incandescent lighting in New York and London, I am inclined to think that perhaps the figure of five watts per candle might apply to the lighting in London, but I do not think that it applies to New York conditions.

John W. Howell: I am not going to say anything about incandescent lights. It has been my pleasure to know Mr. Moore and to know his work during the entire 12 years he has been working on this vacuum tube. At first he showed us a small Geissler tube, and for a long time afterward it was a simple Geissler tube, and when everybody thought that Mr. Moore was chasing rainbows he stuck to his work with a persistence, courage, and enthusiasm which I have never seen equalled. The light which we see to-night is a development from the Geissler tube, and it has been accomplished only by this most persistent work, the progress having been made little by little, step by step, never any very long steps until quite lately. He has at last produced a commercial result. As he says, he has added a commercial illuminant to those which the electrical engineer has at his disposal, and one which has a good many uses in which it excels others.

There may be things in Mr. Moore's paper to criticise. I could criticise some things which have not been alluded to yet, but I have no mind to do it. My only wish is to congratulate Mr. Moore on his work.

Among the uses to which Mr. Moore applies his light the first he names is art galleries. My friend, Dr. Berliner, has just remarked to me that there are many art galleries in Europe which are open only during daylight hours because there is no

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illuminant safe enough to be trusted in those galleries. I think this light would be admirable for such work, because there is no possible danger, except possibly in installing it. If this light could be once installed, the public could have the use of the galleries for much longer hours and with perfect safety.

Leon Gaster: The researches made in obtaining light from gaseous conductors within glass tubes form a decided advance in the conversion of electric energy into light. Bearing in mind however, the progress recently made with the manufacture of incandescent lamps by the use of metal filaments like tantalum osmium, tungsten, zirconium, titanium, etc., or alloys of those metals, with some of which efficiencies are now obtained of about one watt per candle, the practical application of gaseous conductors is somewhat reduced. The great advantage claimed of obtaining properly diffused illumination by the use of the Moore vacuum tube system, can now, to a very large extent, be obtained by the use of the more modern lamps, in combination with proper shades, globes, and reflectors, and by a judicious distribution of the lamps. There is no doubt that a vast field still remains open for the application of this gaseous tube method of illumination.

Will Mr. Moore kindly say whether he has had an opportunity of studying the effect the pink, yellow, etc., colors have upon the eyes, because for the present there seems to be a great difference of opinion as to what the ultimate effect upon sight will be, by the permanent use of such illuminants as the Moore or Cooper-Hewitt types. I should venture to suggest that the illuminating engineers should conveniently have such an investigation carried out, contributing thereby to settle the prejudices and objections which are raised against the use of such types of illuminants. Facts and data gathered from unbiased investigators would form a valuable guide to those who have to advise in these important matters.

Gano Dunn: I am in sympathy with what Mr. Howell has said about the work of Mr. Moore. It is an example of persistence that has seldom been exhibited before. We have known Mr. Moore as harping on his light for so many years that he has become a symbol of the persistent inventor. I am not forgetting to-night, as we are taking the easy course of looking backward upon his work, how very different the forward look was during all the years when we longed for the day when we should have cold light. I was Tesla's assistant at the famous lecture he delivered on cold light at extremely high frequencies; I know of other work in that direction that has failed before and since; I know how we all dreamed of the day when the secret of the fire-fly should be revealed and we should have sticks of cold light wherever we wanted them. Those sticks of cold light we actually see around us in this room. They represent the accomplishment of an ideal the engineering and scientific world has long been struggling for.

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I venture to comment on that criticism of Mr. Moore's paper, advocating photometric efficiency measurements as the only proper comparison of illuminants, by saying that we have a right to take a practical view. Here we are sitting in a room with three alternative systems of illumination at command. Readings which I was permitted to observe just before the meeting, show that when the illumination comes from the ordinary source of lights behind the cove, 10 kilowatts of electrical energy are required. When the illumination comes from the naked lights strung around the border, five kilowatts are required, and when the illumination comes from the tube, four kilowatts. It is obvious to every one of the two hundred members present that the tube consumes less energy and gives a brighter light than either of the other sources. This is a practical fact that no discussion of photometry or brilliancy or efficiency can do away with, and we should give Mr. Moore credit for having accomplished it.

D. McFarlan Moore: I am asked how much gas enters the tube and how often it has to be replenished. The paper states that some tubes have already run about 18 months, corresponding to about 4000 hours, without replenishing. The paper states also that any tube can be replenished, that is, the phosphorous bottle can be replenished, at a neglible cost, so that this tube light is unlike other lights to the extent that the life of the tube itself is practically unlimited because it does not blacken. I am asked what vacuum gauge I referred to. It is a new vacuum gauge, which I developed for this particular work. I did not go into a description of it because the paper is long enough and I wish to reserve that together with a number of other subjects for future papers. I am aiso asked why does not the air enter the tube when the light is out. Mr. Thomas referred to this matter and doubted the ability of a mercury seal to hold the vacuum indefinitely. I know of a number of cases where mercury seals have held perfectly for years. Besides such a valve can be fixed very easily in case there should be any leakage.

Practically all Mr. Steinmetz' criticisms will be found to be answered in the paper. There is one thing that will not be found in the paper and that is a criticism of the illuminating engineers who installed the other systems of lighting which were compared with the tube; in fact they need to be commended, not condemned. The highest talent in the country was procured for the lighting of this splendid hall and the incandescent lighting is done well in all respects. The same can be said in reference to the arc lamps that were compared with the tube. The paper shows the location of these arc lamps, and I am sure that the majority of illuminating engineers would agree that it would be a very difficult problem to locate these arc lamps in any more desirable or advantageous positions than they were located in, in the basement where they were supplanted by the tubes. So with the location of the incandescent lamps in the

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lobby of the well-known theater, which is one of the tests referred to. These lamps are installed in the regular orthodox fashion; that is, in long rows. Fig. 8 shows that they are located in the best possible manner. The solution of the diffusion problem, when using the incandescent lamp system, is to place them as we have them in this room; viz. 92 separate machines in a row to accomplish a certain result which can now be better obtained by one machine, a plain simple tube.

This system of lighting undeniably differs radically from all of the old style systems. It is self-evident that the light diffused from such a large tube more nearly imitates daylight than any illumination that could possibly be obtained from any intense-point source. I maintain that man cannot do better than try to imitate daylight. No form of light will probably imitate it absoluely, but it should be our endeavor to imitate it as closely as we possibly can. Fortunately, it so happens that simple carbon dioxide comes closer to an exact imitation of average daylight color values when used in a vacuum tube than any other form of light. Its superior color values place it in a class by itself. The most delicate shades of colors have been matched under the tube when it is producing the pure white light due to $c\ o_2$. You will note that the 16-ft. tube on the platform which early in the evening gave a 30 hefner per foot light when using nitrogen is gradually changing to a pure white light because it is now adjusted to feed itself $c\ o_2$. The tube lighting this room is being feed with nitrogen and therefore a yellow light results which is the color that gives the greatest efficiency. According to the laws of nature, about twice as much energy is required to develop the necessary wave lengths for a white light, that is, to produce a spectrum that closely corresponds with daylight, than is required for yellow light which has a maximum effect upon the human eye.

The length of life of the tube has been referred to. I said that 8000 hours would be longer than any other form of illuminant—I refer to thoroughly commercial forms of illuminants—and then also assumed the illuminant to be still in perfect condition at the end of the test. It is true that some mercury tubes have had a long life, but at anything like the end of an 8000-hour run a mercury tube is far from clean. This tube will remain at the same degree of transparency for an indefinite period of time, and therefore the maintenance cost for long tube lighting is exceedingly low. My statement about the brilliancy of the mercury light was carefully made. I said a direct glance at the mercury tube. Judging from personal experience, I again state that the mercury tube is harmful to the eye if one looks directly at it. Mercury tubes seem to be efficient in terms of watts per candle-power but a number of them could not light this room as efficiently as this long tube does, to say nothing of the mercury tubes prohibitive color. The matter of breakage has also been mentioned. In all matters of engineering it is

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well to have duplicate units, and therefore large areas are now provided for by equipping them with a number of tubes so that the absence of lights from one tube will be comparable to the going out of an arc lamp or several arc lamps. Such large areas as department stores, for example, can now be perfectly lighted without an inch of wire within their walls.

Fears were expressed that these tubes could not withstand temperature changes without serious difficulties arising due to expansion and contraction of the glass, but practice has proved such trouble to be practically nil and therefore this system is applicable to street lighting. A continuous line of tubing can extend directly above the curb or be supported from the buildings to illuminate the show windows, sidewalks, and streets with a perfectly distributed light.

The best answer to the discussion on power-factors is to state the cold fact that this tube is now operating at this moment at a 75% power factor. Dr. Sharp and Mr. Steinmetz referred to the matter of efficiency and also spoke of the spherical candle-power of the tube. The curves in the paper show the watts per hefner obtained by horizontal measurement of a portion of the tube. I prefer the hefner after having had years of practical experience in trying to use other so-called standards of light. A committee of this Institute after a thorough investigation has recommended the hefner lamp. So far as divisibility is concerned, that is, having lights in small units, much can be said, but I will simply refer you to Fig. 15.

The images of moving objects have been referred to. It is true that a higher frequency is advantageous to a tube of this kind. For a number of years I investigated various methods for overcoming these images; I succeeded to a great extent, but found when I put the tubes on the market that the images were not an important factor at all. Of the two miles of tubing in use to-night there has not been a single practical commercial objection raised on this question. In this connection it should be noted that all who have actually worked under the light speak of its softness and the absence of any eye-strain whatever. Even in machine shops, where it was anticipated the movement of the lathes would be important, turned out to be negligible. On frequencies higher than 60 cycles per minute this trouble disappears entirely, at least so far as the average eye is concerned.

In reference to the tests proposed in a room 40 by 80 ft., I still most decidedly believe that such a method is the only practical solution of the problem of obtaining true commercial relative values of the various forms of light. I said that local conditions must be stated in every test of this kind, but of course I am assuming the local conditions to remain constant for any series of tests on different lights. This room, for example, has a neutral color and uniform fittings, and therefore each light would have a fair opportunity to do its best if the tests were made as directed in the paper. I believe it is the

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duty of all electrical organizations to aid in every way possible to standardize all forms of light, and I do not think this can be accomplished until a room such as I have described has been equipped, and I believe in the interest of science such a room should be established at some convenient place.

The following data were obtained by comparative illumination tests made in this assembly room of the Engineer's Building this afternoon between the Moore tube lighting system and the regularly installed concealed incandescent lamp system and the temporary rectangle formed by rows of exposed incandescent lamps which is the same size as the rectangle formed by the Moore tube.

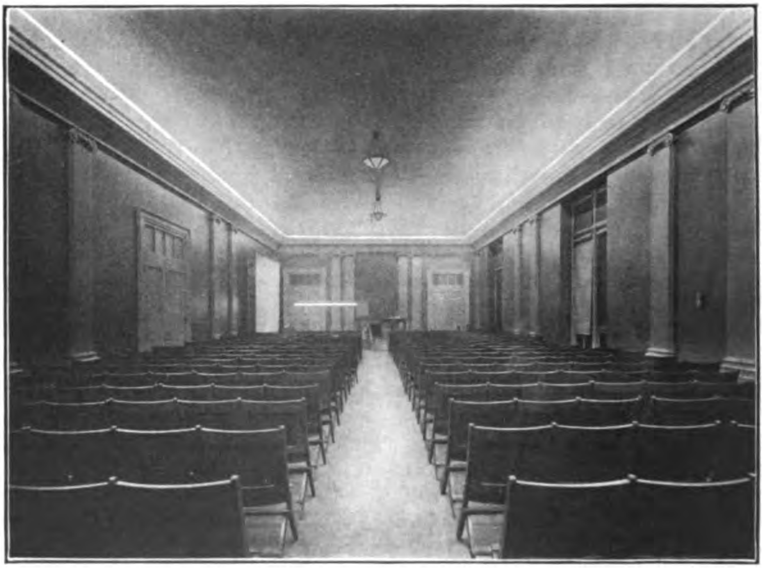

FIG. 1—Assembly room No 2, Engineers' Building, illuminated by the Moore tube light

In these tests a portable illuminometer was used to measure the intensity of the illumination in hefner-feet at nine stations and at a uniform height of 35 in. from the floor.

The Moore tube is made of clear glass and is located as shown in Fig. 1. It is 176 ft. long and forms a rectangle 62.5 by 25.5 ft. It is 1.75 in. in diameter and is not provided with a reflector of any kind. This tube is automatically feeding itself nitrogen, therefore the color of its light is about the same as that of incandescent lamps. Horizontal photometric tests on a portion of the tube 0.5 in. long showed the tube to require 1.6 watts per hefner from the 60-cycle street mains. It was operating at 14.8 hefners per foot, or a total of 2600 hefners.

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The tube having only been recently installed has run only some 25 hours and has not reached its final efficiency, which will be 1.4 watts per hefner after about a 50-hour run and thereafter it will maintain this efficiency indefinitely.

The concealed incandescent lamp system. The tubular 8-c-p. 119-volt incandescent lamps are located behind the cove as shown by the detailed drawing of Fig. 1. A two-way socket is located every 16 in. therefore 288 lamps are in use. Immediately behind each lamp there is a reflector. The lamps and entire equipment is new, having only been used a very few hours. Equally spaced on the longitudinal center line of the ceiling of the room are located 3 incandescent clusters which are concealed by opalescent reflectors each containing 6 lamps of 25 candle-power.

The exposed incandescent lamp system. The temporary circuit of incandescent lamps is installed to parallel the tube throughout its length. It is therefore located close to the tube, between the tube and the edge of the cove so that all of the lamps are exposed and not shielded in any way. They are all new 3.5-watt 117-volt incandescent lamps. They are spaced 24 in. apart, and therefore 90 are in use. Each lamp is in a vertical position.

MEASUREMENTS OF ILLUMINATION.

Engineers' Building, Assembly Room No. 2.

Hefner-feet.

Station	Moore tube system	Concealed incandescent system	Exposed incandescent system
1	4.72	1.72	2.67
2	3.67	2.83	2.37
3	2.90	1.90	2.31
4	2.83	2.40	1.89
5	3.14	1.98	2.07
6	3.83	1.83	2.31
7	4.40	1.61	3.85
8	3.66	1.90	2.47
9	4.90	1.77	2.37
Mean illumination (Average hefner-feet)	3.68	1.99	2.48
Power-factor	75%	1	1
Area square feet	1930.	1930.	1930.
Watts per Square feet	2.15	5.31	2.62
Volts	225.	118.	119.
Amperes	24.5	86.4	42.4
Watts total	4150.	10250.	5050.
lluminating efficiency $\left(\frac{\text{Mean hefner-foot}}{\text{Watts per square foot}}\right)$	1.71	0.375	0.95

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Conclusion

1. That the Moore tube lighting system has 4.6 times the illuminating efficiency of the concealed incandescent lamp system as installed under these local conditions. The Moore tube produces 85% more useful illumination, yet requires 60% less wattage than the incandescent lamp system. This test emphasizes the inefficiency of concealed lighting, and in many cases where the light of incandescent lamps is used to penetrate opalescent skylights an exposed tube can produce an equivalent effect for about one-tenth the power.

2. That the tube produces 57% more useful illumination, yet requires 18% less wattage. Under average commercial conditions this tube would have shown its superiority over exposed incandescent lamps on the basis of 2 to 1. It was noted that the intrinsic brilliancy of the exposed incandescent lamps was too great, but not so that of the tube.

The following tables show the results of the tests that have been made this evening, while this meeting has been in progress. The illumination readings for each of the three systems have been taken at stations Nos. 2, 3 and 4, Figs. 1 and 2.

For convenience in comparison, a table of the readings on the same three stations is abstracted from the complete test made this afternoon.

Measurements of Illumination.

Engineers' Building Assembly Room No. 2.

Tests made previous to meeting. Hefner-feet.

Station	Moore tube system	Concealed incandescent system	Exposed incandescent system
1			
2	3.67	2.83	2.37
3	2.90	1.90	2.31
4	2.83	2.40	1.89
5			
6			
7			
8			
9			
Mean illumination (Average hefner-feet)	3.13	2.38	2.19
Power-factor	75%	100%	100%
Area square feet	1930.	1930.	1930.
Watts per square feet	2.15	5.31	2.62
Volts	225.	118.	119.
Amperes	24.5	86.4	42.4
Watts total	4150.	10250.	5050.
Illuminating efficiency $\left(\frac{\text{Mean hefner-foot}}{\text{Watts per square foot}}\right)$	1.45	.45	.84

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MEASUREMENTS OF ILLUMINATIONS.
Engineers' Building, Assembly Room No. 2.
Tests during meeting. Hefner-feet.

Station	Moore tube system.	Concealed incandescent system.	Exposed incandescent system.
1			
2	3.2	2.7	1.44
3	2.72	2.7	1.11
4	2.33	3.8	1.22
5			
6			
7			
8			
9			
Mean illumination (Average hefner-feet.)	2.75	2.97	1.25
Power-factor	72%	1	1
Area square feet	1930.	1930.	193 .
Watts per square feet	1.97	5.61	2.41
Volts	228.	119.	117.
Amperes	23.	91.	40.6
Watts total	3800.	10840.	4650.
Illuminating efficiency $\left(\frac{\text{Mean hefner-foot}}{\text{Watts per square foot}}\right)$	1.4	0.52	0.52

It will be noted that the "illuminating efficiencies" agree closely with this afternoon's test of the tube system and the concealed incandescent system. The exposed incandescent system is, however, 61% lower because in this afternoon's test the volts were higher than the rated voltage of the lamps. This serves to illustrate forcibly a well known characteristic of the incandescent lamp; that is, their rapid falling off in efficiency with a drop of voltage, for it will be noticed in the first test the volts were 119 as against 117 in the second. The latter being the rated voltage of the lamps, represents the true efficiency based on these three stations. Moreover, since the same ratio would hold for all stations, the illuminating efficiency 0.95 given in the complete test should be 0.6, which would make the tube system about three times more efficient than the exposed incandescent system in this particular case, and after the end of 50 hours' run when the tube will have an efficiency of 1.4 watts per hefner the ratio will be 1 to 3.4. Finally, after 500 hours run, when the average efficiency of the incandescents will be about 4.5 watts per hefner, the tube would show an illuminating efficiency over four times that of the exposed incandescent lamps.

It will also be noted that neither a similar change in the tube voltage nor a considerable change in the tube watts due to adjustment of the gas valve has materially altered its illuminating efficiency.

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The complete test covers symmetrically one quarter of the room, which is also symmetrical, and therefore represents accurately the average illumination of each system. Therefore a room of this kind can be lighted by the Moore tube for one-fourth the cost at which it can be done by incandescent lamps. Similar comparative tests with all other commercial lights will prove the long tube the most desirable. However, there is no cause for alarm, because the adoption of the tube must be gradual and the commercial field is so great that there is plenty of room for all forms of illuminants, each of which will continue to occupy its own particular field. The efficiency race between gas and electricity has always been keen, but I believe the tube has placed electricity in the lead once more.

Reference has been made to art galleries. I will merely add that in order to grasp the spirit of a painting it should always be viewed under the same quality of light it was executed under; namely, daylight. Therefore, the picture should be viewed in the closest imitation of daylight possible and this can be done by using plain carbon dioxide in a vacuum tube.

Mr. Gaster referred to the color problem, and asked as its effect on the human eye. The paper answers that question. The light that comes nearest to the natural light is the one that is best. The nearer we approach to daylight the further away we shall be from doing injury to the eye. There are three factors of importance in connection with injury to the eye so far as light is concerned: color, intensity, and steadiness. The object should be to generate a light at such a low intensity that it can be used in its initiative condition and final condition; that is, without the need of shades, etc. The incandescent lamps or any of the point sources of light need shades either to soften the light or to reflect it, or diffuse it or tone down its color. With the tube method we can decide before we make the lamp just what color we need and obtain it by using the proper gases. I wish to refer to a remark I first made about 10 years ago, namely, that I believe the most important scientific advances of the near future would in one way or another be connected with the vacuum tube. The theory and facts I have presented to-night will, I think, sustain this contention.

Clayton H. Sharp (by letter): In considering the color of the tube with which this hall is lighted, attention should be called to a well marked phenomenon, which doubtless all of you have noticed and which to my mind is very significant. We have seen that when the incandescent lamps are turned on after the Moore light has been in use for so long a time that we no longer find its color particularly strange—the incandescent lights have a very decidedly greenish hue. Their light looks very much like that from an old style incandescent gas mantle when the latter is viewed in comparison with an incandescent lamp. Now we know from actual spectro-photometric measurements that the old style incandescent gas mantle does contain an

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excess of green in its spectrum, and we know also that this is most distinctly not the case with the light from an incandescent lamp. The spectrum of the latter light is continuous and approximates very closely to the spectrum of an absolutely black body; that is to say, all colors are emitted with equal facility. How then do we account for the fact that this light looks greenish when viewed by eyes which have grown accustomed to the color of the Moore tube? It seems to me that the explanation is to be sought by a consideration of some of the simple facts of physiological optics. The green sensation which we get on looking at the light of the incandescent lamp is a color contrast effect. It is produced by the influence on the eye of long exposure to a light which contains an excess of red. In other words, the continuous exposure to the excessive red of the Moore tube causes a temporary red blindness due to retinal fatigue. Under these circumstances any light containing a normal amount of all the colors will necessarily appear strongly tinged with green. It should be noted, therefore, that the green which is seen is not actually in the incandescent light itself, but is a subjective phenomenon induced by the unnatural color of the vacuum tube light. This state of affairs opens up at once a wide field for speculation and experiment on the possibility of more permanent and perhaps harmful effects being produced upon the eye if the Moore tube were used habitually as an artificial illuminant. The advocates of the mercury-vapor light claim that a greenish-hue light is best for the eyes as far as fatigue is concerned, and that red is harmful. If this claim is founded on fact, the light from this Moore tube must suffer greatly by comparison with the light from the mercury-vapor tube. But is this claim well founded? Do we know what hue a light must have in order to make it best for the eyes? We have frequently had expressions of individual opinions on these matters, but as far as I know no thorough-going investigation of our variously colored sources of light to determine what hue a light should possess to enable work to be done by it with the minimum of fatigue has ever been carried out and published in such a way as to furnish practical engineering data on this most important subject. With the widely ranging hues which the illuminants of the present day exhibit, this problem has a significance which was absent fifteen years ago, when parti-colored illuminants were unknown, and it seems to me that the time has come when it ought to be attacked by illuminating engineers and by oculists working in coöperation with each other.

R. A. Fessenden (by letter): A member of the Institute has good reason to be proud of the achievements of his fellow members in considering the history of electric lighting. At the beginning we have the incandescent lamp of Edison and the arc lamps of Thomson and Brush; at the present time it is to members of this Institute that the world is indebted for the

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most efficient developments in the four great classes of electrical illuminating devices. These are:

1. The point incandescence source, represented by the helion lamp of Messrs. W. G. Clark and H. C. Parker.

2. The point arc source represented by the magnetite lamp of Doctor Steinmetz.

3. The tube vapor source represented by the Cooper-Hewitt mercury lamp.

4. The tube gas source represented by the Moore lamp.

It is always unsafe to put a limit to developments in any particular line, but I am inclined to the opinion that these four types will not be greatly improved upon and will remain the standard methods of illumination until they are supplanted by some purely chemical means as suggested by Professor Elihu Thomson. This is not likely, however, for a good many years.

The various other types of lamps such as the tantalum, osram, osmium, tungsten, graphitized filament, calcium arc, Nernst lamp, etc., must I think all be considered as transition apparatus.

The labor and energy spent in devising these types of lamps is not, however, wasted. The development of the metallic-filament lamps, for example, has placed within our hands new methods of obtaining the rarer metals in workable form, and, as in the case of tantalum and osmium, has furnished us with new materials which are bound, sooner or later, to be of use in other lines.

It will be noted that the efficiency of all these types of lamps is in the neighborhood of one watt per candle, and I am inclined to think that by no method in which the light is produced by electricity will this efficiency be much exceeded, except possibly from a monochromatic source.

Mr. Moore's paper must be considered definitely to mark the beginning of a new era in electric lighting. Now for the first time we have a source of electric light which is not intrinsically brilliant and does not need to be shaded or diffused. Also for the first time a uniformly distributed illumination can efficiently be obtained.

Some doubts have been expressed as to the accuracy of Mr. Moore's measurements, but the objections are based upon lack of knowledge of the elementary principles of photometry. It is too self-evident to require argument that a much higher uniform intensity of illumination will be obtained with the same amount of energy from a distributed source than from a localized one.

With reference to the efficiency of the Moore lamp, this agrees almost exactly with some measurements made by me and published in 1901*

Of vacuum tube lamps, many have been suggested. It must be nearly thirty years ago that the first attempt was made to light a mine with vacuum tubes and induction coils. Since then we have had many types, as, for example, Crookes cathode bombardment lamp, and others

*"Light without Heat," *Electrical World and Engineer*, January 5th, 1901:

which, surrounded by a cloud of non-luminous verbosity, have not done much actual illuminating. The only approach to success, of which the writer is aware, is the admirable work of Macfarlan Moore. I know of no reason why his lamp should not ultimately prove a success for certain classes of work, where very long tubes and high potentials are not objectionable. In 1890 I made measurements on the efficiency of vacuum tube illumination, by passing the current a certain time, measuring the candle power of the tube, due to the light from the gas, and then dropping the whole tube into the water. (I was fonder of glass blowing then than I am now.) From the energy put in, (for an ammeter I used a hot wire voltmeter, with silver instead of platinum; this is a good instrument for such work) the heating of the water, and the candle power, the efficiency was determined. It came out quite high, *slightly less than 1 watt per candle power*. Most of the loss was found to be in the heating of the anode and cathode, and this it was attempted to overcome in two ways. First by lengthening the tube, which gave good results, though not commercial, and secondly by making the gas itself the secondary of a transformer. This failed because of too great hysteresis loss in the iron, though one type was not so unpromising.

Some question has been raised as to the commercial future of the Moore lamp. I do not agree with those who hold that its use will be a limited one. While the introduction of any new system is always more or less slow, I believe that in the not far future the greater part of the interior light load of city stations will consist of Moore lamps. The construction of the Moore lamp is especially suited for the coming types of concrete building architecture, and were I an architect I should not consider the lighting of any public hall or lodge room by any other means than a Moore lamp. While it would not pay to alter the present method of lighting the auditorium of the Engineers' Building, I would suggest that it might be worth while ascertaining whether the Moore light could not be advantageously used in lighting the library and some of the halls of the building.

At the same time that we admire the results obtained and the ingenious means by which they are accomplished, we can not help but extend our admiration to the pluck and perseverance with which Mr. Moore and those associated with him have worked on in the face of apparently insurmountable difficulties until they have now finally reached I believe the point of commercial success. It has sometimes occurred to me that much more courage is sometimes shown in financial undertakings than in actual warfare.

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DISCUSSION ON "MOTOR-GENERATORS *vs.* SYNCHRONOUS CONVERTERS, WITH SPECIAL REFERENCE TO OPERATION ON LONG-DISTANCE TRANSMISSION LINES." AT NEW YORK, MARCH 22, 1907

(*Subject to final revision for the Transactions.*)

A. H. Armstrong: In regard to the use of motor-generators or synchronous converters, the question seems to me to be one of voltage regulation. The requirements of a railway system fed from a general transmission system are best met as to first cost and efficiency of operation by the adoption of the synchronous converter, and its almost universal use in railway installations would seem to leave no room for argument. The requirements of a direct-current lighting load can also be best met by the adoption of the synchronous converter, provided the distribution system is used for lighting only. Where, however, the distribution system supplies a mixed lighting and railway load (or any other load occasioning extreme fluctuations) the lighting system should be fed through motor-generator sets in order to smooth out the effect of unavoidable voltage fluctuations. Taking this broad view of the situation, there is a well-defined field for both synchronous converters and motor-generator sets, the question of voltage regulation determining the choice of either type of apparatus.

W. L. Waters: The reliability of operation of these different classes of machines is mainly a question of the care they get in operation. The induction motor is the only one that presents any disadvantages as regards actual construction of the machines. The small clearance between the rotor and stator with which these machines operate makes them more liable to mechanical troubles, and the small slots which it is necessary to use in the stator make it more difficult to make a satisfactory job of a high-voltage winding.

On the question of flashing over, the synchronous converter is decidedly more sensitive than the direct-current generator. The fact that the alternating- and direct-current sides of the converter are so intimately connected, combined with the fact that there is no armature reaction in such a machine to limit the current on short-circuit, make it peculiarly sensitive to sudden fluctuations on one of the circuits. For carrying overloads, the converter is superior to the direct-current generator, but it will not stand short-circuits or violent fluctuations on either circuit so well.

If voltage regulation is of importance, it is practically impossible to use a synchronous converter. With a synchronous converter we are dependent for voltage regulation upon the voltage supplied on the alternating-current side. If the synchronous converter is the only machine on that particular line, then by introducing artificial self-induction into the line and putting a series winding on the magnets of the converter, we can compound the line and so

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to a certain extent make the voltage change automatically with the load; but this means varying the power-factor of the converter and of the system within quite wide limits, and also that this change of voltage on the line affects all other apparatus on that line. The only other way of adjusting the voltage delivered by a converter is by introducing some sort of an alternating- or direct-current voltage regulator or booster, which of course means extra complication, extra cost, and lower efficiency.

As regards corrective effect for power-factor, this can practically be obtained only by the use of a synchronous motor-generator. On account of its low power-factor, an induction motor is very undesirable at the end of a transmission line and would not usually be considered unless it were possible to correct this low power-factor by introducing a leading current into the line. This can only be done practically by means of a synchronous motor. A synchronous converter can be made to introduce a leading current into the line, but this would mean varying the direct-current voltage and power-factor of the machine.

In using a motor-generator at the end of a long transmission line, it would undoubtedly be necessary to employ transformers for lowering the voltage before delivering it to the synchronous motor. In this case the synchronous converter has a considerable advantage in regard to efficiency. The value of this difference in efficiency has to be decided in each case by the cost of producing the extra kilowatt-hours. In a steam plant where the cost of fuel is high, this may be quite important, but as most long-distance transmission lines are operated from water power the cost of producing the extra kilowatt-hours is quite small. Practically, the only bad effect of the lower efficiency is that it reduces the capacity of the power-house machinery somewhat.

The relative cost depends a good deal on the particular machine that we are considering. If we consider a 1500-kw., 275-volt, 25-cycle machine, the synchronous converter would run at about 187 rev. per min., as this machine could not very well be built with less than 16 poles, while the motor-generator set could, by using an interpolar design, be built to operate at a speed of 300 rev. per min. or even higher. In this case there would be practically no difference between the cost of a synchronous converter and that of a synchronous motor-generator set. The introduction of interpolar designs in large direct-current work makes the direct-current generator the equal, if not the superior, of the synchronous converter, at the same time it is not subject to the limitation that the speed is dependent upon the number of poles on account of the frequency.

Referring to the question of starting. The induction motor-generator set is undoubtedly the simplest. The synchronous motor-generator only differs from the induction motor-generator in that it is necessary to close the exciting circuit and to synchronize the machine after it is up to speed. The starting of a syn-

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chronous converter is considerably more complicated than that of a motor-generator. If the converter is compound wound, we have to short-circuit the series coils when starting from the direct-current side. Then we have to synchronize carefully, and an error in throwing the machine on the line is much more liable to do damage or cause a flash-over than in the case of a motor-generator, as there is nothing to limit the short-circuit currents that would flow. If we start from the alternating-current side, we have to see that the polarity and voltage are correct before we throw them on the direct-current line. Throwing a synchronous converter on the line is a more sensitive operation and one which is more liable to cause damage than the same operation with the motor-generator, and in consequence the operator must be proportionately more skilful.

Speaking generally from the operating standpoint, a motor-generator is preferable to a synchronous converter in almost every respect, except as to efficiency and cost. And even as to cost a motor-generator is cheaper for low voltages and larger outputs, especially if the voltage on the transmission line is not over 15,000 volts, when the synchronous motor could be wound to take the high voltage direct. When comparatively cheap and medium-size units are wanted, and under conditions where close voltage regulation is unimportant, synchronous converters would be used; when large-size units are desired and when the voltage regulation and general flexibility are important, motor-generators would be preferable. In situations where the machines are to run with practically no attention, probably induction motor generators would be perferable to synchronous motor-generators. But the fact that synchronous motors can be used to control the power-factor of the line is of such importance in long transmission lines that the engineer should adopt them wherever possible.

H. G. Stott: In regard to Mr. Lincoln's comparison of the characteristics of motor-generator sets and synchronous converters, my own experience confirms his statements. During the initial period of the operation of a water-power plant, the voltage regulation was fairly good, but the speed regulation was poor; with these conditions, the synchronous converter gave the best results, but later, when the number of generators in service had been increased and the line regulation had become poorer, owing to the increased load, we had to resort to motor-generator sets, in order to obtain regulation suitable for lighting.

In reference to the various methods of starting, it is desirable to remember that any method involving starting from the alternating-current side means a rush of current equal at least to full-load current, at a power-factor of less than 25%; whilst starting from a motor coupled to the shaft, or from the direct-current side involves the use of only 4% of the full-load current, at unity power-factor. The first, or purely alternating-current method, may cause a serious disturbance in the circuit, resulting

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in hunting, and violent surges of current and voltage if the circuit is in a condition approximating resonance.

With the induction motor-generator set, however, another condition obtains, as when we start it from a separate motor or from the direct-current end, and after bringing it up to full, no-load speed and throwing it on the line, there may be a rush of magnetizing current equal to more than 10 times full-load current. This is the same phenomenon as observed when throwing current into transformers, the value of the momentary current depending upon the point of the cycle at which contact is made, with relation to the point of the cycle at which the current was previously broken. With large induction motors, it is therefore necessary to introduce resistance or inductance at the moment of closing the circuit, but this resistance may be cut out again after a few seconds, as this enormous magnetizing current lasts only for a few alternations.

Ralph D. Mershon: I cannot quite agree with Mr. Lincoln as to the relative reliability of motor-generator sets and synchronous converters. I have been closely associated with one installation where power is supplied in part by 60-cycle induction motor-generator sets and in part by 30-cycle converters. While there has been very little trouble due to either type of machine, such trouble as there has been, is more chargeable to the converters than to the motor-generator sets, although there are a good many more of the latter than of the former. This is in spite of the small air-gaps of the motors. We have not had in the installation I refer to any trouble such as Mr. Stott speaks of in regard to throwing the induction motors on the line though this may be partly due to the higher frequency. I am quite sure that the company supplying the power would make it known if there had been much disturbance when the motor-generator sets were thrown on the line.

It seems to me that in Mr. Lincoln's introduction, and the discussion of it, there has not been enough stress put upon the fact that operation of the motor-generator set is largely independent of the line voltage which it receives, and that therefore it is very well adapted to operation on very long transmission lines, where the full-load voltage at the two ends of the line will differ widely. In some instances this difference of voltage and the consequent variation between no load and full load of the voltage of the converters at the ends of the transmission line will not be a serious drawback. In other cases it may constitute a serious objection, and in any case it certainly is a very attractive condition of affairs to have along the transmission line motor-generator sets whose operation will not be materially affected by considerable variations of transmission line voltage this will apply to both induction motor-generator sets and synchronous motor-generator sets; but it is also a great advantage at times to have the equalizing effects which may be obtained from a separately excited synchronous motor in assisting to maintain

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an approximately constant voltage on the transmission line. In general, in any engineering problem we must adopt the apparatus to the conditions to be met. Undoubtedly, where the converters can be used without serious disadvantage, there is a very great deal in their favor on the score of efficiency, and also on the score of first cost. I believe with Mr. Waters, however, that if some work were done in the matter of raising the speed of motor-generator sets the difference in cost would largely disappear.

Charles W. Stone: It is simpler to insulate a generator coil than it is a high-voltage transformer coil, for the following reasons: The generator coil is usually small, and when insulated is usually quite stiff and rugged; whereas the transformer coil being comparatively thin and quite wide and flat, making it very difficult to get an insulation which will be continuous and will not be subject to movement and consequent deterioration.

When low-voltage taps on the transformers are used, the starting of converters is much simpler than the starting of a motor-generator set. I have seen machines as large as 1500 kw. started from the alternating-current side and brought up to full speed within 40 seconds. This means, of course, a considerable rush of current, but shows that it is possible in cases of emergency to start a converter quickly; in fact, much more quickly than a motor-generator set of similar capacity.

In regard to the number of hours that the different classes of machines would be out of service, due to defects inherent in the apparatus itself, I do not agree with the order given in the third page of the paper. I should place the synchronous converter first, next the synchronous motor-generator set, and next the induction motor set. I am basing the above conclusions upon a careful study of complaints which have been brought to my attention, and which clearly indicate that there has been more trouble with the induction motor sets than with the synchronous motor sets.

In regard to the relative efficiencies of the different combinations, I would say that the author's table applies only to the 25-cycle synchronous converters, as the efficiencies of the 60-cycle motor-generator set will approach very closely those of the converter sets. The 60-cycle converter will probably cost as much if not more than a motor-generator set.

Mr. Lincoln says that induction motor-generator sets do not hunt. I cannot quite agree with this, as I have seen induction motor-generator sets hunt considerably under certain line conditions. It is possible to make them hunt under test.

The author says, that with the motor-generator set there are two machines to look after. That disadvantage is, I think, somewhat offset by the fact that the converter has very large collector rings and brushes and heavy copper connections. I anticipate as much trouble with the collector rings and brushes as with the synchronous motor end of a motor-generator set.

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Mr. Lincoln also says that the induction-motor end of a motor-generator set has an entirely neutral effect on the line. I do not think that this is quite true; it has a very serious effect on the line, and that is in lowering the power-factor.

Charles F. Scott: Mr. Lincoln's paper is excellent in that it gives a general survey of conditons pertaining to a given class of service. Very often engineers are apt to present a certain class of apparatus as the only one which is suitable; one man, for example, advocates the induction motor; another, the synchronous motor, and still another cares for nothing with alternating current in—it each maintaining that his class of apparatus is the one for all cases. A paper of this kind shows the wide field of conditions which exist, and shows that each of several kinds of apparatus may have its own proper place under certain conditions.

The general conditions applying to the three classes of apparatus considered have been presented; the second step in the problem should be to determine the results of experience. What has been the concrete experience with each these different classes of apparatus? Mr. Lincoln has given his opinion in a certain order of preference of the different classes of apparatus, and some others have expressed opinions reversing his order. If we could get from the operators of the several classes of apparatus their different experiences, it would give us some excellent data. For example, when we are told by one gentleman that induction motor-generator sets give greater cause for complaint than other classes, it raises the question: If this is the case, why is it? The simplest kind of apparatus is the direct-current generator on the one hand and the induction motor on the other, but if, however, these are not found in practice to give the best results, it will be interesting to know more in particular just why.

Philip Torchio: I am willing to endorse all of Mr. Lincoln's conclusions as far as applied to existing moderately-high-tension voltage systems operating relatively short lines. I do not think it justifiable, however, by actual experience to apply the same conclusions to the specific conditions of the paper, having special reference to long-distance transmission lines. In this case experience with synchronous converters is very limited, and the author has pointed out two serious drawbacks which, in my opinion, would in most cases preclude the use of converters. One of these drawbacks is the fact that converters fall out of step when the ohmic line drop exceeds a certain percentage, which is generally limited to ten per cent., and it seems to me that any momentary heavy short-circuit at the end of a long transmission line would be a menace to the continuous operation of the converters. The other drawback is due to the independence between line-voltage fluctuations and direct-current voltage regulation. I am certain that with most of the lighting systems this fluctuation would prohibit the use of converters. I would even go a step further and state that with 25-cycle transmission

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lines, frequency-changers of from 25 to 60 cycles should be installed; not only for the reason of the higher frequency required for good incandescent lighting, but also on account of regulation.

The question of variation of frequency can be remedied at the generating station, but it would be almost impossible to expect the generating station to regulate the distributing voltage with fluctuating loads on the line.

P. M. Lincoln: Mr. Waters says that the synchronous converters would compound the whole line when compounding themselves. This is true to a certain extent only; it is usual in operating converters to place in each individual converter circuit a rather high reactance which has largely the effect of making only the converter compound. Such reactance has the further effect of answering the objection to the large amount of current that a converter would take when short-circuited; the reactance has the effect not only of making the converter compound, but also of limiting the current on the short-circuits. Mr. Waters further says that efficiency is not a very important point, because water power doesn't cost anything. This is an easily answered argument. If power is being paid for, the power wasted has to be paid for as well as that used, and this applies whether the power is generated or bought.

As to the contention that converter speeds are necessarily lower than those of motor-generator sets, I take exception to that statement. I dont see why converter speeds cannot be made as high as motor-generator speeds.

To the statement made in my paper that the induction motor is neutral in its reaction on the line, objection is made that the induction motor is not neutral—that it is highly inductive. Closer reference to my langage will show that my point is that the induction motor is neutral so far as its capability of adjustment is concerned; it takes one position and stays there.

Mr. Torchio intimated that trouble might be expected from converters where the ohmic line-drop was ten per cent. or more. I should like to raise that limit a little, to something nearer twenty per cent., I know of cases where converters have been successfully operated when the ohmic line-drop was considerably more than ten per cent. Also tests have been carried out which indicate that the converters can, under favorable conditons, be operated with an ohmic line-drop of twenty per cent., and possibly more.

B. A. Behrend: I want to ask Mr Lincoln in regard to the subject of his paper why he has not included a 60-cycle converter in the list of machines out of service for a certain number of hours. How many hours would a 60-cycle, 600-volt synchronous converter be out of service?

P. M. Lincoln: I think it would depend entirely upon the time at which the converter was designed. The design of 60-cycle converters has improved wonderfully during the last de-

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cade. If it were designed in the last three or four years, I should put it somewhere between the 25-cycle converter and the induction motor-generator—say 12 hours.

B. A. Behrend: There is another point on which I wish to ask Mr. Lincoln. I quote from his paper:

However, with the modern construction of synchronous machines, including as they do heavy dampers, there is so little probability of hunting that it may be entirely neglected. The only places in which hunting is apt to occur are in cases where antiquated generators are used and where the ohmic line-drop is very high. Neither of these is apt to occur in practice

I am afraid that this statement is not altogether true. I am quite willing to state that hunting does not occur very often, but it does occur in some cases, and in such cases it is often very obdurate and it is difficult to account for the causes in a satisfactory manner. I should like to know why the ohmic drop has such considerable effect; it, of course, limits the overload capacity of the synchronous machine; it changes the characteristic frequency of the oscillation; and if there exist in the system somewhere forced perturbations of a given frequency, then there may be a resonance effect produced by an increase in line resistance. But even this does not explain thoroughly why line resistance is made responsible for hunting. Mr. Lincoln's statement that hunting in modern synchronous machines can be neglected seems to me somewhat broad, although Mr. Lincoln allows himself a loophole by stating that this is the case only with modern generators and converters of a recent style with heavy dampers. I should like to ask Mr. Lincoln why he considers line resistance responsible for hunting?

P. M. Lincoln: Hunting always means that the rotor of the machine that is hunting is departing from its true mean path—periodically ahead of and behind that path. The magnetic field which flows from the pole into the armature is shifting constantly from one side to the other of the pole. The way to prevent that is simply to put grid dampers upon the iron of the pole, and in that case if there is any tendency for the flux to shift across the pole face, large currents are set up in these dampers which oppose the shifting of the magnetic lines.

The application of grid dampers, judging from the experience has been a complete cure for hunting—the exceptions being accounted for on high ohmic drops.

B. A. Behrend: What is the effect of the ohmic drop in regard to hunting?

P. M. Lincoln: I am unable to give you an exposition of the reasons at this time. We have made experiments to determine the limits of ohmic resistance and have found that under favorable conditions the grid damper would prevent hunting with an ohmic drop as high as 20%. The final limit may be even higher than this.

J. R. C. Armstrong (by letter: I am in full accord with the conclusion stated in the last paragraph of the paper, to the

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effect that, "there are but few cases where the motor-generator should be used in preference to the synchronous converter".

I understand that the object of this paper is to determine which of the three devices—synchronous converters, motor-generator sets with synchronous motors, or motor-generator sets with induction motors—is the best for transforming alternating current into direct current, and, at the same time, maintaining a constant voltage on the direct-current bus-bars.

It seems to me that the items "Parallel operation" and "Starting" should precede "Efficiency" and "Cost", as these factors are vital to the successful operation of a plant.

Reliability. or continuity of operation is I think the most important condition to obtain, especially at times when the greatest demand is made upon the respective pieces of apparatus.

I believe that undue prominence and stress has been laid on so called "bucking" or arcing over on the synchronous converters. It is true that this occasionally happens, but in a well-designed converter the percentage of trouble in a station due to this cause is very small. When bucking does occur, very little damage results to the converter, due to the highly developed protective switchboard apparatus installed on the alternating-current and direct-current sides of the converter circuits. It is very seldom that a short-circuit on transmission lines, either on alternating-current or direct-current sides, causes the converter to arc over, due to the fact that the overload device on the breakers will operate and thus clear the station bus-bars. A great deal of the trouble experienced in the operation of converters is due to the fact that the negative side of the circuit has been grounded and no attention has been paid to insulating the machine from the ground. It is readily seen that since there is a short distance between the commutator bars and the frame of the machine, there is only this short distance between the commutator bars and the ground when the frame of the machine is thoroughly grounded. Bucking due to this cause can be very easily obviated by insulating the machine from the ground; in other words, installing it on insulating material that will not allow an appreciable current to pass from the commutator bars to the frame.

In my opinion, the time assumed for the synchronous converter being out of service is too high. I think that this figure (10 hours) can be materially reduced.

Voltage regulation. With regard to the statement in the paper on "Variations in direct-current voltage with variations in incoming line voltage and frequency." I do not believe that such great variations may be expected. Should large variations occur, it would be on an exclusively railway system where the fluctuations in direct-current voltage would not be a serious matter; whereas, where a steady direct-current voltage is required, as, for instance, in a lighting system, the period of fluctuations would be quite long, in fact long enough to allow the operator

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in the generating station to change the field strength on the generator in order to hold the voltage more or less constant. This, I believe, would likewise apply to most systems composed of a combined lighting and railway load. Therefore, I believe that the synchronous converter compares favorably with the motor-generator set and not unfavorably, as mentioned in the paper, for operation under ordinary conditions.

Parallel operation. In the present state of the art of designing synchronous motors and converters, I agree with the writer that "The synchronous motor and converter are on a par in regard to hunting". The question of hunting on the last two mentioned machines may be neglected.

Starting. It might be mentioned in connection with the amount of current that these respective kinds of apparatus take from the line, that the induction-motor set is very bad in this respect. For in the case when a heavy draught of current is taken from the line, thereby setting up line disturbances, the induction motor-generator set is very conducive to this condition.

When new and in good condition, the motor will require a considerable interval of time to bring the machine being started to synchronous speed before switching it on the line. This operation will sometimes take as much as five minutes. A much simpler and quicker method of starting, and one which does not draw a large amount of current from the line, is that of starting from the direct-current bus-bars of the station. This can be accomplished very simply, and no time is lost in waiting to get the machine at the exact frequency of the line. It can be done by sectionalizing the field and connecting the field leads to a multiple-point switch that will introduce into the field circuit when opened a large amount of resistance, thereby largely reducing the normal current flowing in the field, and at the same time causing a very slight increase in voltage on the field windings. With this switch, a tripping device for the direct-current breaker can be operated and connected in such a way that the direct-current breaker through which the machine is receiving its power can be tripped before the high resistance is thrown into the field circuit. A second contact can be attached to this switch for closing the alternating-current circuit on the converter; this operation following immediately the introducing of the high resistance into the field as above mentioned. It will be seen that in the one operation above outlined, three things are accomplished; namely, the cutting off of the starting current, the introducing of a large resistance into the field circuit; and the closing of the oil switch—all three operations following one another in the order named. Then the machine cuts in on the alternating-current side when the armature is practically "floating", due to its own momentum, at approximately synchronous speed, and cut off from the direct-current source of power.

After the above operation has been carried out, the high resistance is cut out of the field circuit by closing the multiple-

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point switch and the machine is then ready for service. It will be seen that there can be very little strain or jar thrown on the armature in starting a machine by the above method. Units of large size can be started by this method by the ordinary operator in one minute or less. Therefore, I cannot see why the more expensive methods as proposed in this paper for starting machines of the above mentioned type should be employed, except perhaps where one of the above methods might be installed for starting one machine in case of emergency when no direct-current power was obtainable in the station.

The above method of starting machines from the direct-current bus-bars is now employed in quite a number of sub-stations in New York where converters are installed. It has been giving entire satisfaction.

In regard to cost of apparatus for starting, it might be mentioned that the cost of installing a switch as described above is only nominal, compared with the cost of other types of starting apparatus.

The advantages of the synchronous converter over the motor-generator are very marked, especially with respect to reliability, which I believe to be the predominating feature. Further, there is a wider range of application of the synchronous converter than there is of the motor-generator.

A. H. Babcock (by letter): A single qualifying clause should be added to the author's conclusions; that is, provided that the line frequency is not greater than 25 cycles. Experience on long lines in the West, especially where an extensive distribution system is operated, shows plainly that synchronous converters should be barred entirely where frequencies as high as 60 cycles are used.

For railway work, especially where the generating station distribution is under one control, and the frequency can be made 25 cycles or less, synchronous converters are to be preferred.

For 1200-volt lines, the indications are that ordinary 600-volt generating apparatus operated in series will give satisfactory results, although there is no experience in this country, at the present time, on which to base a positive opinion.

F. G. Baum (by letter): This paper assumes that 60-cycle converters are as satisfactory in operation as motor-generators. In any event, the author seems to have had in mind a 25-cycle system.

Assume for example that a given district is to be supplied by direct current at several points, also 60-cycle, 2300 to 10,000 volts for light and power circuits from a 60-cycle power system. The substations feeding the light and power circuits are also to be used for the conversion from alternating to direct current.

In this case, to the cost of the converter there must be added that of a bank of transformers and regulators to supply it; add also the losses of the transformers. This would bring the cost of the converters and transformers to about 80% of that of the

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motor-generator, and reduce the efficiency of the converter to about 90%.

The extra floor space for the transformers must also be considered. Also the great advantage the motor-generator set has in regulation on the alternating-current side, as well as on the direct-current side. These advantages are of great importance, and, considered in the light of present experience with 60-cycle converters, the motor-generator would generally be selected for the conditions here assumed. The conditions here assumed are those generally prevailing, except where there is a special system for the railroad power.

Ernest J. Berg (by letter): My judgment is that the synchronous converter is likely to play even a more prominent part in the future than at the present time. I quite agree with Mr. Lincoln in regard to the reliability of the converter as compared with the other types.

Regarding the voltage regulation. I do not think it serious that the power-factor is affected by automatic voltage regulation. Considerable control can be had with but slight change.

In most long-distance transmission lines, considerable lagging current is not objectionable at light loads, because the charging current is larger than the lagging current, due to the induction load. In its control of voltage, the converter can be adjusted to take considerable lagging current at no load and practically none at full load. Therefore, the converter might advantageously be operated with such automatic control. In low-voltage transmissions, which however are outside of the scope of this paper, there would be some objections on this score.

I quite agree with the conclusions given under the heading " Corrective effect " and also under the heading " Efficiency." The question of cost I can hardly pass upon, but I recollect some cases in which the cost of the synchronous converter with its transformer was practically the same as that of high-speed induction or synchronous motor-generators.

Regarding parallel operation. My experience leads me to believe that a properly designed synchronous converter operating on a 25-cycle system can be made quite as stable as any synchronous motor-generator, even if the latter is equipped with various kinds of anti-hunting devices.

Regarding the heading " Starting ". I consider that the three systems are practically on a par. Induction motor-generators will take about as much current as any of the others, if special starting devices are omitted.

My conclusions, therefore, agree with those of Mr. Lincoln, that in most cases the synchronous converter offers advantages over the other two kinds of machine. I consider that in high-potential transmissions where there is usually a leading wattless current, the induction motor is preferable to the synchronous motor in every case.

R. G. Black (by letter): This paper refers to matters that

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interest not only the electrical engineer, but the operating man, the capitalist, and the customer. In my opinion it is hard to consider the various heads under which the paper is discussed for both railroad work and lighting and power work, as what might be entirely satisfactory for railroad work might be otherwise for lighting and power work. From the point of reliability I would say that our experience leads us to differ with the writer of the paper as regards the motor-generator set, as generally designed, resuming operation automatically after temporary cessation of power supply; for if the speed should drop below 50 per cent. it is very doubtful, with the load of incandescent lights, direct-current motors, etc., if the induction motor would resume speed without drawing sufficient current to trip the automatic alternating-current line circuit-breakers. However, with a specially designed coil-wound induction motor, so arranged either by means of a centrifugal device or an electrical device automatically to put resistance in the rotor circuit, should the speed drop, say, 25 per cent. below normal, it is quite possible to arrange a motor-generator station so that the induction motors will automatically resume operation notwithstanding the direct-current load remains on. With motors arranged as above, I should be much inclined to place the induction motor-generator set first on the list, with the 25-cycle synchronous converter second, with about the same number of hours as shown.

Speaking generally, on every point except cost I should be inclined to favor the specially arranged, coil-wound induction motor as being the most reliable, easiest operated, and least objectionable of the three classes of machines discussed. In the matter of cost there is no doubt but that the synchronous converter has the advantage, particularly if its overload capacity is taken into consideration, but unless the operating company controls the transmission company, or has an agreement with them whereby the variation in voltage is not excessive, the cost of a large enough induction regulator brings the cost of the converter, with transformers and regulator, very nearly equal to that of a motor-generator set for a given kilowatt capacity. If the induction motor sub-station is close enough to a terminal station so as not to make transformers necessary, it might in some instances be cheaper than the synchronous converter set.

At one of the plants with which I have been affiliated, which is connected to a long-distance transmission system, arrangements are being made to purchase five 1500-h.p. induction motor-generator sets for lighting and power work in preference to synchronous converter sets or synchronous motor-generator sets, the idea being that they will be much more reliable, easier to operate, and more satisfactory in every way than either of the other types of machine.

Edward P. Burch (by letter): The writer's experience is that 60-cycle converters are not reliable. They are therefore unsatisfactory for 600-volt electric railway service. He would recom-

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mend the purchase of the higher price and lower efficiency synchronous motor-generators in place of 60-cycle, 600-volt converters.

H. W. Buck (by letter): On a miscellaneous system of power transmission covering a large territory it becomes very difficult to adjust the voltage throughout the transmission network to suit everybody, where each customer is directly dependent on the line voltage at the point of delivery of the power. This condition becomes more pronounced as the length of transmission lines is increased. With a trunk line, say 200 miles in length, feeding branch lies here and there of considerable length, it is virtually impossible to maintain anything like a uniform potential on all parts of the system, nor is it possible to prevent wide fluctuations in the voltage at any given point. Sudden changes in load are inevitable, together with changes in phase relation. Such power systems should not be closely restricted in regard to line voltage regulation but should be free to deliver power, in the rough, so to speak, with voltage refinements made on the secondary distributing circuits. The power company should be allowed a variation in line voltage of 20% if necessary, or 10% above and below a mean. Such fluctuations might not be objectionable for many classes of power work, but would, of course, be prohibitive on lighting circuits. It becomes necessary, therefore, under these conditions to have the voltage of the secondary distributing circuits rendered independent of the line voltage, and motor-generators must be installed.

It is true, as pointed out by Mr. Lincoln, that frequency variation with a motor-generator installation disturbs the distributing generator voltage; but on large transmission systems having a heavy and diversified load, as is usual, good frequency regulation is not difficult. The loads on various portions of the system, and consequently the voltage at such points, may fluctuate widely, but in general the total resultant load at the main power house remains either practically constant or else changes so gradually that the governors can compensate for it with small change in generator speed.

As to the comparison between induction and synchronous motor-generators, while the induction type has certain advantages in starting, the synchronous type has other advantages of equal importance. In cases of momentary short-circuits on the system there will be a tendency for all the motor-generators and converters to drop out of step, due to the consequent drop in voltage. In the induction type the torque drops as the square of the drop in voltage, and a heavily loaded induction motor may therefore break down at a comparatively small reduction in impressed voltage. In the synchronous type, the field current of the motor being proportional to line frequency only, will remain constant under drops in line voltage, and will tend to keep up the voltage at the motor terminals, and maintain the torque. In this regard the converter has the same

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characteristics as the induction motor, in that its field current falls with the voltage of the line. In the writer's experience the motor-generators of the synchronous type hold in step better under line short-circuits than either converters or induction motor-generators.

The absolutely independent control of the voltage of the distribution circuit possible with the motor-generator combination affords many operating advantages, all of which cannot be listed on paper. The possibility of independent phase control with the synchronous type is of special advantage. On every alternating-current power system there must of necessity be many small induction motors in operation, and compensation for their low operating power-factor can only be obtained by means of some large synchronous motors on the lines. The introduction of single-phase railways as customers on large power systems, with the low power-factors of their circuits, makes this corrective influence all the more demanded.

O. B. Coldwell (by letter): Mr. Lincoln places " Reliability of operation " at the head of the list of points to be considered when making a selection of the most suitable machine for the connecting link between the high-tension transmission line and the low-tension direct-current distributing system. Unquestionably this is the point of most importance to those entrusted with the operation of a plant using such apparatus.

It has not been the experience of the writer that the converter has a decided advantage over a motor-generator set, on account of there being but one machine to get out of order rather than two. A converter is necessarily provided with slip-rings on the alternating end—six rings in the case of large converters—and even with the best of attention there will occasionally be trouble on this side of the machine. This feature is entirely absent in the motor-generator set.

The induction set is driven by a unit that, when once in operation, has a decided tendency to remain so in spite of momentary disturbances on the high-tension system which would invariably cause the synchronous motor and the synchronous converter set to drop out of step. Due to the intimate relation existing between the alternating-current supply circuit and the direct-current end of the converter—both being connected to the same set of armature windings—and to the fact that the sliding contacts on the alternating-current side are to be taken into account as well as the commutator, I should consider the converter as the least reliable machine when inherent defects in the apparatus are used as a basis of comparison.

I should therefore revise the table of relative reliability due to defects inherent in the apparatus to read as follows:

Induction motor-generator 10

Synchronous motor-generator 14.

25-cycle synchronous converter 17.

I agree with Mr. Lincoln that it is an advantage to be able to

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control the voltage independently of the supply circuit. Undoubtedly the converter is handicapped in this respect. In railway work this is not of such importance as in the case of lighting apparatus.

As to the "corrective effect," the synchronous motor-generator set is the only unit under consideration that can be used for the purpose and at the same time not suffer a disturbance of the direct-current voltage. Unless the "corrective" features of the synchronous motor and converter are applied intelligently, more harm than good may result.

The synchronous converter is the best machine as regards efficiency. Mr. Lincoln's calculation is apt and shows very plainly the advantage enjoyed by the converter in this respect.

Regarding cost, the writer is of the opinion that 60% is somewhat low for the converters, as it is necessary to consider the step-down transformers, the voltage regulators, the blower for air, cooled transformers, and the more expensive construction due to the necessity for an air chamber under the transformers.

Parallel operation is equally good for all machines.

The induction motor-generator set is the best as regards starting, as no synchronizing is required. In some of the larger sets, however, it is customary to start them on direct current and bring them to speed before connecting them to the supply circuit, thus avoiding any serious shock on throwing on the line.

No mention is made of the use of half or one-third or two-thirds taps for starting the converter on the alternating-current side. This is undoubtedly the quickest way of starting a converter and connecting it with the line. It is successfully used.

The use of the storage-battery in central sub-stations where a large direct-current, low-tension lighting system is installed, as well as a direct-current railway system, for the purpose of acting as a relay on the alternating-current supply from long-distance transmission lines, should in some cases have a bearing upon the selection of apparatus. In such case the battery could carry, during times of trouble, the low-tension system directly and the railway system indirectly, the transformer machinery being operated inverted.

While converters have been and are operated inverted, they are not so successful in this respect as the synchronous motor-generator set.

It is the writer's opinion that a selection of apparatus should be made only after a very careful study of all the operating features of the particular case in hand. It is quite possible that the best results could in some cases be obtained by using both converters and motor-generator sets. A discussion of this particular feature should bring out some interesting points.

W. R. C. Corson (by letter): The problem of determining the best method for converting alternating to direct current for any particular case must, of course, be largely dependent on the

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governing conditions of supply and the purpose of the derived current. Mr. Lincoln's treatment of the subject, by classifying the operating requirements of such apparatus, and noting the points of relative vantage which the several methods possess in each class, is an analysis which aids in a solution of the problem. But it is, after all, a problem which is not susceptible of a general solution. The several classes of operating requirements should be given differing relative values in considerations involving the choice of apparatus for differing purposes or conditions. The summary of Mr. Lincoln's paper, which seems to establish the preëminent excellence of the converter because it is found superior in a majority of counts, is, however, really of little assistance and serves only to establish an explanation for its present almost universal employment for the conversion of alternating to direct current. There are conditions of operation in which the synchronous converter falls behind its competitors in filling the essential requirements, and any conclusion that will help us in a limitation of these conditions will be useful.

Under the head of reliability, the synchronous converter is given the highest award, because but a single machine is involved as against a unit of two machines. The conclusion would follow that the converter is therefore twice as reliable as any method of double conversion, were it not for the further numerical values for the relative reliability advanced by the author. Now the relative reliability can hardly, it seems to me, be measured by the number of hours that the apparatus would be out of service within a given time, even if we could all agree on a basis for estimating the probable hours of breakdown. A more reasonable valuation of reliability would be the ratio of operating time to that of breakdown; but here again any exact assignment of values would be so much a matter of personal opinion that no definite conclusion could be reached. The mathematical chance of pure accident is greater in a unit of two machines than in a simpler apparatus, but reliability, from the practical viewpoint, should involve other considerations than the mere mathematical chance of accidents from unforeseeable causes. We must take the risk of accident, in this sense, in almost any responsibility we assume, and can rarely place a value on such risk.

Reliability, for the purposes of this discussion, should cover the broader field of ability successfully to operate under adverse or abnormal conditions, and the weight attached to the measure of reliability, as thus defined, possessed by any class of apparatus should be in proportion to the probable diversion from normal of the conditions for which a selection is to be made. Reliability, in other words, should be understood as the possession of robust characteristics as opposed to those sensitive to adverse conditions.

For general ability to withstand the hard knocks of fluctuations of voltage, frequency, or load, or of heavy overload, and to operate with a minimum of attention under all circumstances, the induction motor is without a peer. A direct-current genera-

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tor coupled to it to form conversion apparatus can be designed to possess the best characteristics of such a machine uncompromised by the conditions imposed by the alternating-current supply. From the point of view of reliability I should, therefore, place the induction motor-generator set in first place; the synchronous motor-generator in the second; with full appreciation of its merits under proper environment, I should give the synchronous converter the lowest mark of the three.

The characteristics of the several types of converters as affecting the control or regulation of the direct-current voltage is considered by Mr. Lincoln, and his conclusion that relative numerical values of merit should not be attempted on account of the variable conditions dictating a selection is correct. He points out one case in which the synchronous converter can not be used; as no case appears against the other types, perhaps in this particular group of characteristics the converter must also take last place.

The corrective effect of the converting apparatus on the line is a matter of importance in the proportion which the capacity of that apparatus bears to the total load on the line. It is clearly shown in the paper that circumstances of control make this effect a desirable or undesirable characteristic. The induction motor-generator, having no corrective effect, may be, therefore, in this count, either utterly worthless or preëminently excellent, but under either consideration the converter seems to have second place.

In efficiency, the converter is undoubtedly the superior of either of the other types with which it is compared, and it is unquestionably its superiority in this respect which influences most largely its almost universal selection. It does not seem quite fair, however, to allow to the converter quite the measure of superiority credited by Mr. Lincoln's figures for efficiency. These, I understand, are admittedly made on the assumption that the line voltage is " too high for a revolving machine and must be transformed before utilizing." This assumption is of a condition which is usually necessary to converter operation but by no means so to that of its competitors. To give them the benefit of the doubt, it would be fair to decrease the figure representing the economical superiority of the converter by an amount determined by the static transformer losses. If this were admitted, the relative economy of the different types would be represented by the following values:

Synchronous converter	91
Synchronous motor-generator	85
Induction motor-generator	84

The first cost of a synchronous converter installation is much less than that of the other types, but again the cost of step-down transformers, and usually of additional switching equipment, should be included with that of the converter itself in the comparison.

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The parallel operation of all types of machine under consideration can be accomplished successfully under normal conditions. Under certain abnormal conditions, however, either type of synchronous apparatus is more sensitive than the induction motor-generator.

In starting characteristics, Mr. Lincoln's analysis places the induction motor-generator set at the head of the list, the synchronous converter second, and the synchronous motor-generator last. The reasons for this rating appear sufficiently obvious.

In his summary, Mr. Lincoln concludes that as the synchronous converter excels in his analysis in counts 1, 4, and 5 and is practically at par with the best in count 7, there would seem to be " but few cases where the motor-generator should be used in preference to the synchronous converter." From my rating of the characteristics of the types considered, it appears that in counts 1, 2, 3, 6 and 7 a form of motor-generator is inherently superior to the converter, while only in counts 4 and 5 does the converter take unconditionally the first place. But counts 4 and 5 are usually factors of prime importance in the choice of apparatus, and the characteristics required by the other counts are possessed in sufficient degree by the converter. The conclusion is undoubtedly true, then, that but comparatively few cases exist where it should not be used. In fact the conclusion is so obvious that this discussion would be of little value, did it not, as it does, indicate by its analysis the conditions which would determine the selection of other apparatus in these few cases.

Where the synchronous converter is but one portion of an electrical system designed, installed, and maintained as a whole, for the particular purpose of the direct-current supply, the conditions most suitable for converter operation will be provided. The frequency, voltage, regulation, etc. will be selected with particular reference to the purpose of the conversion, and the control of all apparatus will be subject to one management, or at any rate to a common interest. In installations of this character, reliability of performance, adjustment of voltage, corrective effect on line, etc. will be maintained within the limitations of converter characteristics by the provisions of the entire system, and the manifest economy and low cost of such machine will secure its selection.

On the other hand, where the purpose of the conversion is merely incidental to the general purposes of the whole system, conditions less favorable to converter characteristics are more prevalent, and problems of selection will arise. In such cases, independence of purpose of demand and supply may often be best served by the electrical independence of the machine utilizing the supply and that supplying the demand.

So far as any general conclusions may be drawn from a discussion of this character, therefore, I would advance the proposition that the criterion of utility of either of the conversion methods considered lies in the degree of community which the purpose of the supply bears to that of the demand.

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Henry Floy (by letter): It must be borne in mind that Mr. Lincoln's conclusions are very general and may not apply to any particular or individual case. A paper of this character is so frequently accepted as conclusive and universal application attempted, that I desire to show how unsuited these general conclusions may be in some cases. For example, it is practically impossible to use a converter, without storage-battery, to supply satisfactory lighting service at the end of a long transmission line that also serves alternating-current motors carrying large fluctuating loads, because the motor load will disturb the alternating voltage which directly affects the direct-current voltage. A motor-generator would therefore be necessary, regardless of the general conclusions, or the advantages claimed for the converter. Again, if the voltage of the transmission circuit were not so high as to prohibit the use of motor-generator sets without step-down transformers, a considerable investment, always necessary with a converter installation, would be saved.

Under the item of "cost" it seems to me that Mr. Lincoln has not clearly indicated the relative investment necessary, because the converter must be provided with some voltage-control apparatus that, from the comparative figures given, do not seem to be included in Mr. Lincoln's costs; moreover, if a motor-generator can be used without transformers, the converter installation with transformers and regulators will usually make the total converter cost higher than that of the motor-generator.

In a section where lighting is troublesome, I believe an induction motor-generator will be found much more satisfactory than a synchronous motor or a converter, because the induction motor will frequently pick up its load again without the shut-down of the other machines that will ordinarily result from the short-circuit caused by a lightning flash.

I do not agree with Mr. Lincoln in regard to the reliability of the different types of machines, for although the converter is but a single unit, it is twice as liable to some causes of break-down as either a motor or a generator, because it is connected to two circuits—on its alternating and its direct end—and would therefore suffer, for example, from lightning coming in through either circuit.

Clarence E. Gifford (by letter): It goes without saying that insulation of apparatus operated from a motor-generator can not suffer directly from "surges" on the line from which power is supplied to the motor.

It is equally true that direct-current apparatus operated from converters often has its insulation subjected to very severe strains by such surges, especially surges that arise from momentary grounding of one of the lines of the supply system.

It will be readily seen how such a ground, or a permanent one, were it permitted to remain, may, and generally does cause a strain between the earth and any conductor connected with

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the secondary winding of a transformer supplied from a system upon which such ground occurs, or with any portion of a transformer or successive series of transformers which are operated by current received from said secondary. And this condition does not necessarily imply any change in voltage between the primary lines, one of which is grounded, although a change would doubtless occur.

The surge is transmitted through a transformer or series of transformers in the same manner as through a condenser; or in case of a ground of more than momentary existence, the entire secondary system would have its insulation from earth subjected to a series of strains recurring with the same frequency as that of the current. The primary and secondary windings of a transformer would in this case correspond to the plates of a condenser, and the action is not likely, in most cases, to be greatly modified by the core, unless it be well grounded.

Numerous experiences prove that the strain between earth and a direct current 220-volt system operated from a converter receiving power from a 22,000-volt system through three step-down transformations, often rises momentarily, when no preventive measures are adopted, to thousands of volts, and at a season of the year when the power company cannot say "lightning." In one instance two direct-current motors grounded at the same instant that the power company lost a cable, and from appearances one not familiar with such occurrences or with the circumstances would certainly have pronounced it the work of lightning. Incidentally, it is interesting to note the inventive faculty displayed by the "experts" of some power companies in assigning any cause but the true one for these expensive occurrences.

The best protection against such effects that the writer has found, and it has proved remarkably satisfactory in a trial extending over many months, is to place at various points in the direct-current system, notably near the converter, near the extremities of long trolleys and near stationary motors, carborundum resistances of 1000 to 1200 ohms (for a 220-volt system) bridged between the lines and having the center well grounded.

Ordinary resistance rods of a resistance of 250 to 300 ohms, such as used in lightning arresters serve well. Each one may have terminals of No. 10 or No. 12 copper wire attached by winding the wire once or twice round the copper plated terminal of the rod, twisting it down tightly and soldering it by dipping. The resistance of each, in ohms, is then determined marked upon it plainly with paint.

They are then sorted and made up in series of four, with all joints soldered, in such manner that the resistance between the center and one extremity of any series does not differ from that between the center and the other extremity of the same series

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by more than two or three ohms. Any other style of leakage devices used for the same purpose must of course be practically non-inductive, rugged, and so proportioned that when a dead ground occurs on one side of the local system the current flowing through the device shall be just safely below a point that would injure the device or its connections.

As before noted, the best protection for any local system operated from long-distance lines, is likely to be secured by distributing a number of such leakages at points where theory and experience indicate the greatest need. Unless the current value of a surge exceeds the ordinary, the potential between the system thus protected and the earth will not rise to a dangerous point.

As an indication of this fact, one plant in mind required five to eight new lamps per month for a ground detector, the lamps receiving normally only one-half full voltage, and this was not due to ordinary grounds on the system.

Since leakages, as described, have been provided, the detector lamps escape destruction, and crane operators cease to fear being knocked nearly senseless, as has occurred in the past, but the most noticeable result is the great decrease in number and seriousness of motor troubles.

Wm. B. Jackson (by letter): Under the list of "points" which are considered in the paper, it seems to me that the subject of "*Parallel operation*" should either be omitted entirely and considered as being covered by the subject "*Reliability*", or that it should be placed second in the list. Without perfect parallel operation "*Reliability*" as considered in the paper would be of little value.

1. *Reliability*. In this matter I take direct issue with some of the statements made in the paper. It is true that the the synchronous converter comprises but one machine, but it it is equally true that this machine is the weakest brother in the entire family of alternating-current and direct-current machinery. It is formed from a combination of a revolving armature alternating-current synchronous motor which, considered as an alternator, is no longer an acceptable piece of machinery, and of a direct-current generator which has been designed, not as the best possible direct-current generator, but as the best generator that can be made a component part of a synchronous converter.

The argument against the motor-generator set on account of pressure and insulation would be more nearly correct if reversed, for there can be no reason for using a higher voltage on the alternating-current side of a motor-generator set, unless it has evident advantage over the lower pressure. Furthermore, a first-class stationary armature induction or synchronous motor can be safely insulated for several times the pressure that can be employed in a synchronous converter armature with equal safety.

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Although, as stated in the paper, the fault of "bucking" is not one of very serious moment in present day practice, yet this fault can be eliminated with greater ease and certainty in a simply direct-current dynamo than in one which must also work in with an alternating-current frequency of even 25 cycles, and this fact is emphasized if 60 cycles is considered.

2. *Voltage regulation.* I am unable fully to agree with the conclusions arrived at under this heading. I do not consider that, "All methods under discussion are equal" for "automatic change in voltage with change in load" for the reason that the automatic results that can be obtained in the synchronous converters are dependent upon various extraneous conditions, while such results are obtained in motor-generator sets with the same simplicity as in any direct-current dynamo, for the direct-current side of the machine, and in the synchronous motor-generator set very effective regulation on the alternating-current side can be obtained with simplicity and without interaction with the direct-current operation of the machine.

In considering the "ability to adjust the initial voltage" it is impossible to accept the statement that the introduction of an alternating-current booster on the converter shaft is a more "logical arrangement so far as initial voltage is concerned than the motor-generator." Such an arrangement with its regulating rheostat and switches certainly does not constitute so logical an arrangement for voltage regulation as a simple rheostat in the field of a direct-current generator.

In considering "variations in direct-current voltage with variations in incoming line voltage and frequency" I agree in general with the conclusions arrived at, though I consider that too much relative importance has been given to the difficulties arising from variable frequency. In most up-to-date transmission plants where the "line voltage is too high for a revolving machine and must be transformed before utilizing", the problem of maintaining uniform frequency has been solved, though this cannot be said as regards the problem of uniform delivered voltage.

Under "Corrective effect" my views agree with those expressed in the paper, though it should be added that in the case of almost all high-tension transmission plants there is direct telephone connection between the power house and all sub-stations containing current-transforming apparatus. As these sub-stations usually require continual attendance, they thus become a valuable adjunct of the transmission system, and especially so if synchronous motor-generator sets are used therein.

4. *Efficiency.* There appears to be an error in computing the additional value of synchronous converters as compared with motor-generator sets, when considered simply from

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the standpoint of relative efficiency. The capitalization of the saving due to the higher efficiency of the synchronous converter is made upon a basis of 6 per cent, while in fact 10 per cent. is the least figure that should be used in this connection. This would be upon the basis of 5 per cent. interest upon the money involved and of 5 per cent. for depreciation or sinking fund.

There are some factors that enter into this consideration which have advantageous bearing upon the motor-generator set, and have not been considered in the paper. In sub-stations supplying mixed service, uniform step-down transforming apparatus can frequently be used for all classes of service when motor-generators are employed, while two ratios of transformation must be used if synchronous converters are operated. Also, in the case of very large converter units, the handling of the great quantity of alternating current at from 350 to 450 volts which is required is sometimes a factor of considerable importance.

There are also cases where, even for plants of the class here considered, an extra set of transformers must be provided for synchronous converters that would properly be omitted in the case of motor-generator sets. Such a condition is presented where the high transmission voltage must be reduced at the outskirts of a city to permit of carrying the current into the distributing stations located in the city.

5. *Cost.* Under this heading the same additional considerations that are presented under "*Efficiency*" should be taken into account to arrive at a fair analysis of the relative importance of synchronous converters and motor-generator sets, when considered from a broad point of view.

6. *Parallel operation.* Although it is true that troubles from imperfect paralleling qualities are not of frequent occurrence in up-to-date transforming machinery, yet the motor-generator sets have the advantage. In fact during those times when unending troubles seem to come upon the operating superintendent in a bunch, as they sometimes do in the best regulated plants, the synchronous converters are usually the first to show signs of distress, and this is especially true in plants of higher frequencies, while motor-generator sets are not so prone to crankiness. In motor-generator sets, troubles arising in the direct-current side of the system cannot have magnetic or electrical effects upon the alternating-current side, nor can troubles arising in the alternating-current side have such effect upon the direct-current side. This cannot be said of synchronous converters.

7. *Starting.* The question of starting has been well presented, but considering that an error in starting is likely to cause vital trouble in the synchronous converter on account of its commutator and collector rings, and also that the revolving-field synchronous motor properly connected to a high-class direct-current generator is a more robust piece

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of apparatus to withstand synchronizing mistakes, it does not seem fair that the synchronous converter should be placed ahead of the synchronous motor-generator set as regards starting qualities.

Summary. In the foregoing, I have more particularly considered the advantageous qualities of the motor-generator set, as it had seemed to me that the advantageous features of the synchronous converter have been very fully presented in the paper. There has been no thought of belittling the field of usefulness of the synchronous converter. At the same time, I do not feel that the phrase in the "*Summary*" "that there are but few cases where the motor-generator should be used in preference to the synchronous converter" should go unchallenged. In fact, there are large appropriate fields of usefulness for both the motor-generator set and the synchronous converter, though it is fair to admit that the conditions will doubtless warrant a greater number of synchronous converters than of motor-generator sets being put into service.

R. S. Kelsch (by letter): The writer has used both motor-generators and synchronous converters. There can be no rule which makes one better than the other. Local conditions, class of service, number of units, and the characteristics or nature of the system from which they are operated entirely govern the advisability of using one or the other.

Farley Osgood (by letter): We are operating ten converters driven by current from our power station and transmitted about 60 miles at 33,000 volts at a frequency of 60 cycles. Four of these converters are 30 miles, three are 45 miles, and three are about 60 miles from the power station, and are placed in three different sub-stations, and, at times, all operated together.

These being 60-cycle machines, I presume they are the most sensitive type of synchronous converter in use. We find that these machines are very reliable, and, generally speaking, the interruptions to service are caused by the flashing-over at the brushes on the commutator. These machines have been in service for three years.

The first year's experience with the converters brought them into ill repute as regards reliability; but a careful study of the situation showed that the real difficulty was the lack of voltage regulation on the generating end. Regulation conditions were bettered by means of the water-wheel governors, and the installation of a voltage regulator. Since the correcting of the voltage regulation, or during the last year and a half, the ten converters have thrown themselves out of service less than ten times, giving an average of better than once per year per converter. I think this is as good a record of running as can be shown by any other type of machine driven from a source of power of high voltage and used for railway work.

These machines are 430 volts on the alternating-current side,

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and furnish 600-volt current on the direct-current side. They are connected with the high-tension system of 33,000 volts by means of a step-down transformer with a reactance coil in series between the transformer and converter.

Our experience shows that converters with bad voltage regulation on the alternating-current side are the worst things an operator can have; but with good voltage regulation, which with existing regulating appliances is wholly possible, the converter is entirely satisfactory and preferable to the other two types of machines under discussion.

Our experience with the converter also brings out the fact that although a sudden rise of 10 per cent. of the voltage from the generating source is liable to make the converter flash-over, a very great drop in the generating voltage may occur without affecting the converter.

Three times we have had a generator oil-switch stick so that the machine was thrown in and out of service several times in rapid succession, and so disturbed the line voltage as to lower it on the indicating voltmeter from 110 to about 65, and yet on none of these occasions were the 60-cycle converters thrown out of step so that they went out.

Concerning the "*Corrective effect*". When the load of our system is so arranged that the power and lighting load is carried on one transmission line, and the railway load on the other; in other words, when there are only induction machines on one line, we have materially to increase the voltage on this line in order to bring about any satisfactory power-factor. In mixed service work, therefore, the converter will help the voltage at the generating end by bringing about a more satisfactory power-factor. We find that an induction load only will perhaps require an increase in potential of from three to five per cent. at the generating end, but by placing converters with the induction motors satisfactory results are obtained on the receiving end without this increase in potential, This is simply an actual operating condition mentioned to bear out a well-known theoretical supposition.

Concerning "*Efficiency*". The experience on the system here, which carries converters at three sub-stations at a total transmission length of 60 miles, shows that with the proper arrangement of load we can obtain the power-factor as indicated by Mr. Lincoln; namely, 95 per cent.

Concerning "*Parallel operation*". We find no difficulty in operating our 60-cycle converters in parallel, not only with each other in the same sub-station, but in parallel with other converters in other sub-stations. At first the converters did not all appear to be of equal efficiency; it was found, however, merely to be a matter of adjustment, the large apparent differences of efficiency being easily done away with

One noticeable feature in a converter, which, however, is probably a well-known fact, is that the different phases of any

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one converter will not require the same amount of current, and that the various phase requirements vary.

As we use single-phase recording watt-hour meters to measure the current taken by the converters, we can very easily observe the current requirements of each phase of the machine. Often the meter will change its speed in favor of another phase of the converter sufficiently to be observed by a man watching the meter discs. The daily record of consumption taken from these meters shows swings from one phase to another from one day to another.

In summing up these discussions, I would say that I would not recommend any type of machine other than a converter for railway work from a high-tension source of power.

John C. Parker (by letter): The writer has been much interested in the particular phase of voltage regulation that bears on the distribution of load between various machines and between systems fed by distant hydroelectric generating stations on the alternating-current lines and engine-driven or local hydraulic plants on the direct-current lines.

In any large works or city distribution, it is customary to generate at a high voltage, 2500 to 11,000 volts, and distribute by means of this voltage to various sub-centers, where transformation to either the railway or light and power circuits is effected. The motor-generator set possesses, in such a case, one decided advantage over the more ordinary form of synchronous converter, in that the load taken on by any one station may be varied by manipulating the field excitation of the generator without influencing the power-factor of the alternating-current lines, and vice versa. Thus, during a period of maximum activity in any one section of the distribution system, the direct current voltage may be depressed, causing more distant sub-centers to feed into and relieve this particular district by means of the direct-current network, whereas with synchronous converters the tendency is for the converter nearest the concentrated load to assume increasingly greater proportions of the load until its automatic apparatus cuts it out of service. Of course, the inherent regulation of the converter can be made so bad as to give a strong drooping characteristic even at a good power-factor, but this is evidently at the expense of the copper efficiency and leads to voltage variations which are manifestly objectionable—especially on lighting systems. With the motor-generator set, the load fluctuation can be guarded against and the direct-current voltage regulation at the same time kept reasonably near what it should be, by designing the generator so that the voltage will progressively rise with increasing loads, until at any desired load point it begins to drop and thence rapidly decrease to a value below the no-load voltage, thereby causing current to flow in from distant transformation points which may be less heavily loaded.

Inasmuch as hydraulically generated power must be sold on

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what is in all cases the equivalent of a peak-load basis, we often find installations in which 24-hour power is received from a distant hydroelectric plant and is supplemented, on the peak, by a local steam generating plant. In such a case the vagaries in the transmission voltage or momentary peaks in the load demanded on the direct-current system may result in a heavy overload in the alternating-current transmission. A few of these peak overloads will heavily affect the consumer's bill. Here again the synchronous converter suffers a disadvantage that cannot be obviated otherwise than by juggling with the power-factor, which is manifestly prejudicial to the distribution system. A motor-generator set having a slightly rising voltage characteristic on the generator up to normal load, followed by a rapid droop, tends to take a more nearly constant load. Such characteristics are additionally important when the voltage regulation of the steam-driven local plant is bad.

It should be pointed out that the alternating-current booster or induction regulator referred to under caption two of Mr. Lincoln's paper, permits the application of automatic relays to the system for accomplishing such load control, and indeed permits a more direct regulation of load than can be obtained with motor-generator sets. On the other hand, this introduces additional elements of unreliability into the system, one of which, the relay, is especially delicate, while the induction regulator must be very substantially designed if it is to stand up under the severe treatment to which it is subjected. It is obvious that neither of these methods permits so nearly instantaneous operation in the division of load as does a motor-generator.

The elements of relative efficiency and cost would seem to be a function, more or less, of the specific voltage used in distributing to the various transformation units. If, for example, it were necessary to use such a subsidiary distributing voltage as 2500 or 11000 volts for works distribution, or for entrance to and distribution underground in a city, the element of transforming cost would be eliminated in the case of the synchronous or induction motor-generator which might operate directly at either of the voltages mentioned, while additional transforming equipment would have to be used with the synchronous converters. In all probability, this would still leave somewhat of a margin in both the matter of efficiency and of cost in favor of the synchronous converter, but probably not a very large margin. If in addition, an alternating-current booster or induction regulator were installed, the efficiency and cost, as well as the reliability of the converter, would suffer somewhat additionally. The complexity of the equipment would also be materially increased. The writer is inclined to feel that a distributing system of 2500 volts would show a worse case for the synchronous converter than would a distribution voltage of 11,000, inasmuch as this higher voltage would react much more prejudicially on the cost, efficiency, and reliability of the synchronous motor than

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it would on the transformers which would probably—following the modern practice—be made oil-insulated for this voltage.

In a number of cases a material advantage accrues to the motor-generator set from the less room it occupies as against the synchronous converter, step-down transformer, and—if this feature were included—the alternating booster or induction regulator. Whether this and a few other elements mentioned would throw the balance one way or the other between the two types of apparatus, would seem to be a question controlled by the special considerations in any given installation, such as the size of units and voltage on the distributing alternating-current transmission system.

H. F. Parshall (by letter): The synchronous converter is the more advantageous machine to use when the conditions of transmission and distribution are such that the ratio between direct-current and alternating-current voltage is more or less fixed. When the line drop is considerable, and a constant or increasing direct-current voltage, according to load, has to be maintained, the synchronous converter is at a disadvantage. When however, the reverse is the case, the synchronous converter has the advantages of higher efficiency, less first cost, and, in favorable cases, greater capacity for extreme overload. The motor-converter stands in an intermediate position between the motor-generator and the synchronous converter. It has not the flexibility of the motor-generator in the matter of voltage transformation and has not the high efficiency of the synchronous converter. Now that the development of computating machines for high speeds to suit the requirements of turbo-machines, is assuming a satisfactory status, it appears very reasonable to suppose that, in most classes of long-distance transmission, the balance of advantages will lie in the use of motor-generator sets. In other cases, however, where the ratio of transformation can, from the nature of things, remain more or less constant, the balance of advantages will lie with the synchronous converter, so far as efficiency and first cost are concerned.

A. C. Pratt (by letter: While Mr. Lincoln's analysis of various means of obtaining direct current from transmitted alternating current is fairly stated, it must be born in mind that the choice of a proper medium will depend largely on the governing conditions of the particular installation. In all systems reliability is essential. While 25-cycle converters are satisfactory, 60-cycle converters may be termed successful. But they are not always a comfort to the operating engineer and are certainly more apt to develop internal troubles or go out of step when slightly unfavorable conditions arise, than are induction or even synchronous motor-generators.

In the operation of converters there seems good reason for providing separate motor-driven exciters, in which case voltage fluctuations not accompanied by change of speed will have much less effect on the operation.

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In many long transmission systems voltage regulation or corrective effect, singly or together, are the governing conditions when designing a sub-station. If converters are used, either one of these features may be provided for with reasonable success; but it is by no means easy to cover both at once in such a way as not to affect other branches of the system unfavorably.

A poor power-factor in the transmission system may readily cause a greater drop in over-all efficiency than the difference between the efficiency of converters and motor-generators, provided the latter results in a good power-factor in the system. The ideal system transmits power current only; the idle current needed at various consuming points is generated at these points; permitting less capacity in generators, transformers, and transmision line, and better regulation at the consumer's end. The synchronous-motor generator in large size units with a motor of unusually ample size offers means of attaining closely the ideal system.

Steadiness of speed is usually much better maintained than steadiness of voltage on a transmission system; therefore the generator of a synchronous motor-generator set will regulate well, and a first-class regulator applied to the exciter of the motor will afford the corrective effect for the alternating system. Under these conditions, alternating-current lighting and direct-current railroad load can often be supplied from the same bus-bars with excellent results. It must be borne in mind that the synchronous motor-generator requires slightly more intelligent supervision than induction motor-generators, but not more than the converter. For best results, therefore, the synchronous motor should be used under immediate supervision of the transmission company.

Another item for consideration is the character of the direct-current load as regards inertia effects. Some loads, like lighting, store no energy, while some motor-driven loads store a large amount of energy when coming up to speed. Assuming a load of the latter type, supplied from induction motor-generators, and a momentary short-circuit cleared by time-limit circuit-breakers on some one feeder out of the sub-station. During the short-circuit the induction motors will slow down much more than will the generators at the power station. The sudden removal of the short-circuit will cause a sudden rise of voltage, which in turn will cause a rush of current to the induction motors; these, hampered by large inertia, will very likely trip their breakers before attaining normal speed, or the speed will have dropped so low that the motor torque is reduced to a point below full-load torque, in which case there is little probability of recovering the load.

Under the same conditions, if the short-circuit is not too severe, a synchronous motor having a high "pull out" torque will stay in step and hold its load. This observation applies also with especial force to induction motors, of relatively low "pull out".

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characteristic loaded with heavy shafting or air compressors, in which case the load torque is not reduced as speed is reduced. The same motors would show entirely different results when driving centrifugal pumps.

Leo Schüler (by letter): It may be interesting to discuss the subject of this paper from the European point of view, as there is so distinct a difference between American and European practice. I dare say that on this side of the Atlantic the number of converters in operation does not exceed one-tenth the number of motor-generators, while I think that in the United States the opposite ratio may safely be assumed. As a matter of fact, I do not consider the author's conclusions, which are generally in favor of the converter, to be quite impartial, and for the following reasons:

I see no reason to assume "a somewhat variable frequency." Governors for all kinds of prime movers can certainly be obtained so as to keep the speed constant within one or two per cent. and with proper care variations of frequency of more than one per cent., can certainly be avoided. We may therefore safely assume a virtually constant frequency.

The author assumes "the line voltage to be too high for a revolving machine." this means more than about 15,000 volts; as such voltages are only employed in long transmission lines, it seems only fair to assume further that a considerable drop of pressure takes place on the line, say 20-25 per cent. It should be well understood, that with a lower pressure the comparison would be more in favor of motor-generators, as static transformers could be avoided.

1. *Reliability.* I do not understand why "with the motor-generator, other conditions may dictate a very much higher motor-voltage," as static transformers are distinctly specified.

It is true that under normal conditions the possibility of "bucking" is about equal with 25-cycle converters and direct-current generators. It must be kept in mind, however, that the sparkless running of the commutator in a generator depends only upon the direct current taken from it, while in a converter it is also affected by the conditions of the alternating-current system. The 60-cycle, 600-volt converter has necessarily such a high pressure between adjacent commutator segments that it must be set quite at the other end of the reliability list.

As I consider the synchronous-motor to be a little more reliable than the induction-motor, in consequence of larger air-gap, I should figure the reliability to be about as follows:

25-cycle synchronous converter Synchronous motor-generator	12 hours.
Induction motor-generator	14 hours.
60-cycle synchronous converter	25 hours.

2. *Voltage regulation.* There can be no doubt but that the direct-current voltage supplied by a motor-generator depends only upon the direct current taken from it, while in the case of a con-

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verter it is greatly affected by the alternating-current voltage.

It must certainly be assumed that the alternating-current voltage supplied to a sub-station by a long transmission line is variable, not only in consequence of the variable power consumed in this individual sub-station, but it also affected by other sub-stations, starting of motors, working of lightning-arresters etc. in any other point of the system. As the effect of all compounding arrangements, with or without reactance or boosters, is based on the magnetizing effect of the direct current taken from the converter, they certainly will not respond to independent fluctuations of the alternating-current voltage. It is therefore impossible with converters to obtain automatically a constant direct-current voltage with a variable alternating-current voltage; this reason alone, I think, simply forbids the use of converters for lighting purposes in connection with long transmission lines.

Summary. As the converter has certainly a distinct advantage with regard to efficiency and costs, while there is practically no difference with regard to starting, I would summarize as follows:

For 25-cycles, railway or other motor circuits, converters are always preferable. For 60-cycles, motor-generators are more reliable and should be adopted if costs and efficiency are not prohibitive, especially if the primary pressure is low enough to allow omission of static transformers.

For lighting circuits, converters are applicable only if the alternating voltage itself is sufficiently constant for lighting purposes.

Carl Schwartz (by letter): *General.* Synchronous converters are extensively used where three-phase alternating current of high potential and a frequency of 25 cycles is to be transformed into direct current. For the other higher standard frequency of 60 cycles, this type of machine is not nearly so satisfactory in operation as a motor-generator. As reliability is of prime importance, particularly in long-distance transmission, and as a synchronous or induction motor-generator is much more reliable, the converter does not need to be further considered in case of this or similar high frequency.

Mr. Lincoln clearly and briefly enumerates the various advantages and disadvantages of the three types, but on account of the great amount of detail to be considered it is impossible to balance the characteristics of the different constructions entirely against each other without taking specific cases; therefore the choice of one type or the other will always be governed by the prevailing conditions. If this were not the case, the choice could be left to the purchasing agent instead of to the engineer.

The following suggestions are offered to illustrate that a somewhat different point of view may change some features of one type to the advantage of the other.

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Reliability. Mr. Lincoln considers the converter the most reliable machine, quoting as an advantage that there is only one machine instead of two, and that a low alternating current voltage has to be applied. As it is assumed that in both cases step-down transformers are to be used, there seems to be no reason for applying an unsafely high voltage in case of a motor-generator; in this respect, then, both types should be considered equal, inasmuch as the voltage for a motor-generator could be much higher than for the converter, without impairing its safety beyond the comparable limit. The chances of a breakdown may seem twice as great, because the motor-generator contains two rotors and two stators, while a converter has only one armature, and one set of field coils. The machines are, however, practically alike otherwise, assuming that the motor-generator has two bearings only. If the case warrants, spare armatures and field coils can be kept in stock, minimizing the consequences of a break-down.

An induction motor is less affected by line troubles than either of the other two constructions; on a long line this motor is most undesirable, and in figuring on this type of machine, the increased investment in copper or capitalized line losses should be charged against it.

Voltage regulation. With reference to voltage regulation, the converter is at a serious disadvantage. Boosters, potential regulators, or other devices in connection with the converter are undesirable additions, and influence items 1, 4 and 5, and, to a certain extent, item 3, in favor of the motor-generator. These complications were apparently not taken into account when comparing the machines in regard tor eliability, efficiency, and cost. The efficiency of the converter will be decreased by from one or two per cent., and its cost increased by from ten to twenty per cent., so in trying to make the converter equal to a motor-generator in regard to voltage regulation, its advantages may be counterbalanced to a large extent.

Efficiency. In considering the additional costs of current for the motor-generator against converter, inclusive of the regulator, and assuming an efficiency of 85% and 91% respectively, the following is submitted:

A low efficiency increases the direct operating expenses in coal, water, wages, etc., but not the fixed charges, as the power station will hardly be built larger on account of a slightly lower efficiency of transforming-devices. The cost of current per kilowatt-hour can therefore be estimated perhaps closer to one-half than one cent., decreasing the annual additional costs for current in case of the motor-generator to about **$950.** In capitalizing this amount, depreciation and other fixed charges should be included, for the reason that if the amount capitalized is invested in equipment it will have to be treated like other portions of the system.

Using 10% to cover all fixed charges, the annual extra costs

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for current represent an investment of $9500, or $19.00 per kilowatt capacity. The exact amount will depend on local and other conditions, and the difference may be still lower; for instance, in case of a water-power plant, or if the operating costs should otherwise be lower than five cents.

In most instances it will be almost impossible for the engineer to decide definitely which type of machine should be selected, before bids have been obtained, based upon specifications, outlining carefully all requirements, and leaving room for the manufacturer to specify the characteristics of the equipment he is able to offer.

Guido Semenza (by letter): The only point not put forward in this paper is, perhaps, the one excluded by the assumption "that the line-voltage is too high for a revolving machine and must be transformed before utilizing." This is often not the case, at least in Europe, where synchronous motors wound for 12,000 volts are in regular operation. Some firms would not hesitate to construct them for still higher voltages.

In such cases the cost of installation, the floor space occupied, the switching apparatus, and the efficiency of the motor-generator set are not very different from those of a converter with its transformers. Thus for primary voltages up to 8000 volts, in view of its other advantages, the motor-generator is generally preferred.

In Europe the use of converters is not so general as in the United States. This machine has been highly perfected in America, and its advantages have been only lately acknowledged on the old continent. Then again, for countries where hydraulic power is available, and long-distance transmission is the rule, there are special reasons for the preference being given to motor-generators, as I shall try to explain.

In the matter of power transmission and distribution many differences exist between one plant and another. We have, for instance, power plants of the type of the New York Edison Company's, in which the alternating current generated is mainly converted to direct current in a number of sub-stations belonging to the same company. The alternating voltage is then very carefully controled in the power house, in order to obtain the best direct-current regulation, and all systems used in the different sub-stations to control the voltage are there working in the best condition.

Assume, for example, a long-distance power transmission, say 100 miles long, from a waterfall. Consider that the power is sold in the neighborhood of the station, at the end of the line, and along the line. Suppose further, that there is a steam station working in parallel for overcoming the winter peak. We see that these conditions are quite different from those of the first instance, and voltage regulation cannot be done except to take care of the converter sub-stations.

In such a type of plant, rather common in Europe, converters

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can be put in for railway work, but it would not be very easy to obtain a good direct-current lighting service. In such cases motor-generators are preferred.

In plants of the above kind, the "corrective effect" of synchronous machinery, if any be used, is very important in order to correct the low power-factor given by induction motors. What Mr. Lincoln says on this point is quite right: it is much easier to control the corrective effect with synchronous motors than with converters in which the corrective effect and direct current are interdependent. I would let customers use synchronous motors, and I would not allow them to use converters on a somewhat complicated distribution plant, as they would only take care of their direct-current regulation without paying any attention to the power-factor.

Another matter in connection with long-distance transmission is the parallel running. It is well known that when the ohmic resistance of the line is too high, also good synchronous machines are apt to hunt and sometimes to such a degree as to get out of step. This is an extreme condition, but a certain amount of hunting may easily occur.

It is also known that by adjusting the excitation this hunting may be reduced. It is evident that in these conditions the motor-generator offers a great advantage, as this regulation can be done without affecting the direct voltage.

All these considerations show that the problem proposed cannot be solved in a general way: there are conditions in which the converter is, no doubt, the best adapted machine; there are others in which only a motor-generator ought to be used, and others also in which the use of either is equally as good.

On the comparison of synchronous versus induction motors, I must say that for driving-current dynamos the synchronous motor is, in a general way, for many reasons preferable. It is not always true that after a momentary removal of the voltage from its terminals the induction motor will resume operation automatically: if it is well loaded it will often shut down and cause its own circuit-breaker to open when the voltage is restored.

The use of induction motors has to be resorted to only in case starting from the direct-current side is not possible. When starting on the alternating-current side causes too much trouble, and in the case of very long transmission lines where some difficulties are experienced with parallel running.

B. C. Shipman (by letter): *Reliability.* If reliability were the sole requirement of the problem, the induction motor-generator would, in my opinion, be the best transforming apparatus to use. Mr. Lincoln states no defects under this head against the induction motor-generator, except that higher voltages than 700 on the motor may be required by certain conditions. If the choice were between synchronous converters and induction motor-generators on the ground of reliability

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alone, certainly whatever voltage was available for a synchronous converter would also be available for the induction motor-generator. Therefore there would be no advantage on this point for either piece of apparatus. Of course it might be much more desirable to use a higher voltage, and the induction motor-generator would lend itself readily to this condition. Even so, I think the latter apparatus would still be on a par with the synchronous converter, as it is much more easily insulated and less susceptible to injury than a commutating machine.

The strong point of the induction motor-generator is pointed out in the paper; namely, automatic resumption of operation after an interruption to the service. All the weak points of the synchronous converter, however, are not covered. Synchronizing takes more or less time, certainly more than it takes to get an induction motor on the line, and it has to be done more frequently. "Bucking" of a synchronous converter also takes place more frequently than of a similar direct-current generator, for several reasons aside from the sudden removal of load. "Pumping", or even sudden aperiodic changes of speed in the prime movers, will cause a synchronous converter to "buck". In such cases there is a shifting of the field similar to that caused by the sudden removal of load. A synchronous converter, is also more often reversed by bucking than is a direct-current generator; hence its greater tendency to bucking counts considerably against its reliability as compared with a similar direct-current machine. Therefore I would change the numbers given in Mr. Lincoln's paper showing the relative amounts of time the respective machines are out of service, as follows:

Induction motor-generator	10
25-cycle synchronous converter	14
Synchronous motor-generator	17

Voltage regulation and corrective effect. I concur in all the author's remarks under these heads. I have noted excellent regulation of direct-current voltage from a synchronous converter equipped with an induction regulator, when supplied from generators whose other load was street railways.

Parallel operation. Of course with similar units, parallel operation presents no difficulties or disadvantages of one type over another. Sometimes, however, if a synchronous converter or a synchronous motor-generator is operated in parallel with an induction motor-generator, there is trouble in making the units divide the load properly throughout the full range. Assuming a constant frequency and voltage, the induction motor-generator will have to be compounded decidedly more than the direct-current end of either synchronous unit. A variable frequency or voltage, or both, will interfere with any fixed adjustment, so that under the conditions laid down in the paper under discussion, hand regulation would probably be necessary to effect good distribution of load between units.

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Summary. In general, I agree with the author that in the majority of cases with conditions under discussion, the synchronous converter has the advantage.

Miles Walker (by letter): I am interested in Mr. Lincoln's paper on account of the discussion which has recently taken place in England between the advocates of the converter on the one hand, and the advocates of the motor-generator and the cascade motor-converter on the other.

It is mainly in the case of 50-cycle and 40 cycle-transmissions that difference of opinion exists as to the merits of the various types of machines. In the case of 25-cycle transmission the superiority of the converter for most purposes is generally admitted.

The Bruce Peebles-La Cour cascade motor-converter is now much used in England for transforming 50-cycle alternating power into direct-current power. On the other hand, the 50-cycle converter is also widely used, and the excellent performance and great stability of modern designs are fast overcoming the prejudice which existed in England against high-frequency synchronous converters.

In most cases where the matter is discussed in England, it is not permissible to assume that the line voltage is too high for a revolving machine and must be transformed before utilizing, because generally the line voltage is only 6,600 or 11,000, and with motor-generators the use of transformers is obviated. Notwithstanding this advantage in favor of motor-generators and motor converters, it can generally be shown that the use of transformers and converters is preferable on account both of reliability and economy.

Reliability. The risk of breakdown of a converter and its transformers is less than that of a motor-generator set. If one transformer out of three breaks down, it is possible to run with only two, and it is easy to substitute a spare transformer. It takes a long time to rewind a motor-converter.

I have seen a 50-cycle converter take six times full-load current momentarily without " bucking " or getting out of step, so it cannot be said that it is a delicate machine. It will not, however, stand a dead short-circuit.

I know of a case where three 1000-kw. 40-cycle converters have been installed for electrolytic work where continuity of service is of vital importance, because in case of a shutdown some hundreds of cells of molten electrolyte have to be refilled from a furnace at enormous cost. The plant has now been in operation six months without any failure on the part of the converters, although some motor-generators alongside of them have already been out of service more than the 17 hours allotted to them by Mr. Lincoln.

Voltage regulation. I agree with what Mr. Lincoln says in this division of the subject. The method of introducing self-induction into the transformers is applicable to most cases where a

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range of only 10% is required in the adjustment of the direct voltage. The power-factor on load need not be varied more than between the limits of 95% lagging and 95% leading current. In many cases the required adjustment is only 5% and the power-factor need not depart more than one or two per cent from unity. Very few users object to a leading power-factor, particularly at heavy loads.

Corrective effect. I agree with what Mr. Lincoln says in this division of the subject.

Efficiency. In dealing with this matter in England, we have generally to consider the losses in the transformers as well as in the converters, because these are in competition with cascade motor-converter sets on which very high efficiencies are guaranteed (93% on the 500-kw. size).

The converter and transformers are however still ahead in efficiency. It is safe to guarantee 94% on the 500-kw., 500-volt rating for the over-all efficiency of the converter and transformers and this without rating up the converter so high as to spoil the overload guarantees.

A well-designed 50-cycle converter can take very heavy overloads without commutation or heating troubles. It is therefore safe to keep it loaded to the full in cases where it would not be advisable to keep motor-generators fully loaded on account of fear of sudden demands for power, so that in taking the all-day efficiency of a converter, it is fair to take the efficiency at a higher percentage of the load than with a motor-generator. Here is a case in point: at a certain sub-station belonging to the North Eastern Railway Company the load fluctuates between almost zero and 1600 kw. A load of 1200 to 1600 kw. lasts at times for about one minute. The whole of this load is taken by one 800-kw., 40-cycle converter. Compare the efficiency of this sub-station with what it would be if the converter were replaced by, say, two 500-kw. motor-generators.

J. B. Whitehead (by letter): Under the author's assumption that transformers are used with all three types of machine, his conclusions appear reasonable. Attention may be directed, however, to the many instances of moderate transmission distance and voltage in which it is possible to apply the line voltage directly to either type of motor-generator, but to the converter only through the medium of transformers. The relative position of the motor-generator under such circumstances is bettered, not only as to reliability, but also as to efficiency and cost. Considering reliability, this improvement would be greater in the case of overhead than in the underground transmission in cities. The figure for the efficiency of transformer and converter becomes about 91%, the figures for the motor-generators remaining the same. The relative cost will now be approximately: converter and transformers 82%, motor-generators 100%. In many instances these differences may be sufficient to outweigh the more general choice of the converter, and indicate the motor-generator as the proper machine.

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DISCUSSION ON "THE PRACTICABILITY OF LARGE GENERATORS WOUND FOR 22,000 VOLTS," AT NEW YORK, MARCH 22, 1907.

(*Subject to final revision for the Transactions.*)

B. A. Behrend: I stated that hydraulic turbines for large capacity, of 7500 kw. or above in individual units, are not likely to be of great importance at the present. The extensions at Niagara Falls may contain such large individual units; I hardly think that for the Victoria Falls of the Zambesi, units of 7500 kw. will be installed. Our chairman, Mr. Mershon, will probably bear me out when I say that the units for Victoria Falls will be about five thousand kilowatts. In all these cases the line potential will be high, and, therefore, the generators will not have to be wound for very high potentials. I believe, therefore, that my statement, that water-wheels need not seriously be considered as prime movers for large generators wound for high potential, is correct.

Let us take for example the system of the Interborough Rapid Transit Company of New York, in which generators wound for 11,000 volts are used; if the capacity of this system were larger and the area of distribution greater, 22,000 volts would have been seriously considered as the potential of the generators, rather than install units of 6600 volts or 11,000 volts transforming from this voltage to 22,000 volts. It must be distinctly understood that the potential of the generators is altogether dependent upon the conditions of the system of distribution.

I agree with Mr. Lincoln that reliability is more important than cost. To be able to keep a plant going is, in my opinion, the most important thing from the standpoint of the manufacturing and operating engineers. I want to call attention to the fact that repairs on high-speed generators are more difficult to make than on low-speed generators, as the coils are larger and more difficult to handle. This relates especially to turbo-generators and it forms, therefore, another weighty consideration against the use of high voltage in turbo-generators. Small hydraulically operated power plants in which 600 or 800 kilowatts are generated, will be simpler if no oil-filled transformers have to be used. As these plants are sometimes located in the mountains, this may be an advantage in certain cases. These generators are usually easy to repair, whereas repairs on oil-filled transformers take considerable time. Few power plants, therefore, care to depend upon repairs of transformers, but prefer to use a spare transformer. The 150-kw. generator which has been referred to in this paper was wound in two days, including the making of all connections. In Fig. 1 of this paper there are shown two efficiency curves, the one marked "*A*" referring to a 150-kw., 2200-volt, 600-rev. per min., 60-cycle, three-phase generator, and the other marked "*B*" referring to a 150-kw., 22,000-volt, 600-rev. per min. 60-cycle, three-phase generator. I have also plotted a curve which represents the difference in losses between "*A*" and "*B*". This loss corresponds to the

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loss in transformers used in connection with the 2200-volt generator, therefore, the efficiency of the high-voltage generator would be approximately equal to the efficiency of the low-voltage generator with the transformers. As far as I can see, the efficiencies are nearly the same in both cases. In Fig. 2 there will be found the regulation curves of the 22,000-volt generator, showing a regulation of 4 per cent. at a power-factor of 100 per cent. The temperature rise of the armature coils at 3.5 amperes is 16 or 17 degrees by resistance, and only 10 degrees by thermometer. I want to call particular attention to the difference in temperatures between the outside of the coil and the inside, so that, the temperature rise on the inside being, for instance, 60 degrees, the temperature on the outside might be only 30 degrees.

C. E. Skinner: The feasibility of using generators of 20,000 to 25,000 volts has been of very great interest to me for a number of years. In my opinion there are three main factors which must be considered in any discussion involving the use of these higher voltages directly on the generator: 1. cost of installation; 2, reliability of service; 3, performance of plant.

Cost of installation. I do not agree with Mr. Behrend that the question of cost can be left out of the discussion. I put the question of cost of first importance. Generators of 20,000 volts and above would hardly be considered at all for use in transmitting directly without the use of transformers unless there were some gain in cost. The decreased cost of such an installation of generators where 20,000 to 25,000 volts are used results from the omission of transformers, and some switchboard apparatus, and the requirement of less space for installation. Generators for a given output will be larger for the higher voltages, more lightning protection will be needed, and, according to Mr. Behrend's figures, a larger amount of money will be tied up in spare parts, particularly with relatively small plants. It is difficult, if not impossible, to make a general statement as to the relative cost of the two systems, as much depends on the size of units, the amount of power to be delivered, and the general requirements for handling the system. Without having made actual calculations, I believe that there are many cases where the cost of installation would be equal, if not greater, with high-voltage generators than with low-voltage generators and transformers where sufficient margin is allowed in spaces to insure the same reliability of service.

Assuming a plant of 10,000 kw. total, with generating units of 10,000 kw., the capacity of machinery installed would have to be double the output on account of requiring spare parts. If units of 5000 kw. are used, 50% must be added to the equipment. If the same plant is equipped with low-voltage generators and step-up transformers, it is my opinion that no spare generator would be required. If but one unit is used with three transformers in delta, it will be impossible, in case one trans-

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former breaks down, to operate without additional transformers—using two transformers in *V*. If the transformers are star-connected, one-third additional capacity in transformers would be required if a spare transformer is carried. Many plants operate year in and year out without spare transformers, and with much higher voltages than it is possible at the present time to use directly on the generators.

The constructional difficulties of high-voltage machines are much greater than with low-voltage machines and transformers. In a unit of any given size the number of conductors increases approximately in proportion to the voltage, and the cross-section of the conductor decreases inversely as the voltage. Armature coils are therefore mechanically much weaker, and, where the coil-throw is long—as in low-frequency machines, particularly low-frequency turbo-generators—the question of coil supports becomes more difficult as the voltage is increased.

Static and lightning troubles increase as the voltage increases; consequently, even for the same number of volts per turn, the insulation between turns must be greater with the higher voltages. The outer insulation increases approximately in proportion to the voltage. As a result the copper space in a given size of slot rapidly decreases and will eventually disappear. Very large slots are therefore necessary, and, to further the economy of insulation, the coils must be reduced to the lowest possible number.

Reliability of service. High-voltage machines are necessarily more subject to break down from all causes than are low-voltage generators; they are also harder to protect from lightning discharges of the same voltage. Repairs for the average machine are more difficult to make than for the average transformer of the same voltage. This feature has, no doubt, influenced Mr. Behrend in making the statement that it is necessary to carry complete spare parts for high-voltage generators.

The question of lightning protection is of great importance in any transmission system, and I believe the concensus of opinion among experienced engineers is that a generating station consisting of low-voltage generators with step-up transformers will be far easier to protect than a similar station using high-voltage generators, assuming the generator voltage to be between 20,000 and 30,000 volts. I have recently visited two stations using generating voltages between 20,000 and 30,000. The first has been in operation for some time, delivering power to the Valtellina Railway near Lecco, Italy. The generators are 20,000-volt, 3-phase, 15-cycle, direct connected to water wheels. That the lightning problem is a serious one at this station is proved by the fact that even though a large variety of lightning-arresters is installed, on several occasions the burning out of a generator has resulted from lightning discharges. At the time of my visit, additional types of lightning-arresters were in the station ready for installation in the hope that they would give relief from

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this difficulty. The second station referred to was not in operation; this is the Subiaco-Rome transmission, the generators being water-driven and the generating voltage 28,000. The whole installation including generators, switchboard, etc., is beautifully simple, but it remains to be seen whether this simplicity will exist after one or two seasons of operation.

Performance of plant. As before stated, high-voltage generators necessarily require open slots, the slots must be larger than those for low-voltage generators; and for economy of insulation the minimum number of coils must be used. This results in relatively high iron-losses and relatively poor regulation. At the present time there seems to be very little demand for 20,000- to 25,000-volt apparatus, except as additions to plants built some years ago.

Mr. Behrend says that steam turbines of 10,000 to 15,000 kw. and even 25,000 kw. will soon be developed and put into successful operation. There are already in operation a number of units which, while not rated at 10,000 kw. are, virtually of this capacity, and there are under construction steam-turbine units of 10,000 kw., with an overload guarantee. From 11,000- to 13,200-volt generators are in successful operation in this country; and one plant, the Los Angeles Edison Company, has been operating 7500-kw., 16,500-volt generators for some time.

I agree with Mr. Behrend that generators wound for voltages of from 20,000 to 25,000 are entirely feasible and that as soon as there is any real demand for such machines they can be successfully made. As before stated, it is chiefly a matter of cost, and it is also a question whether or not they are worth while. It is well known that a well-distributed winding gives better results both as to the performance of the generator itself and of other apparatus on the circuit, especially synchronous apparatus. The high-voltage generator plant is therefore at some disadvantage as compared with the low-voltage generator, step-up transformer plant in this regard. If large amounts of power are to be transmitted some distance, there will be used voltages higher than it is possible to use on generators at the present time. If for transmitting relatively small amounts of power within distances which can be reached by 20,000-volt transmission, the individual case must be considered. The cheapest outfit that will give equal reliability of service will, without doubt, be selected in every case. The use of such transmission plants would be limited to districts where large amounts of power are to be transmitted comparatively short distances; for instance, for railway service in large cities such as the present system installed in New York City, this being at the present time 11,000 volts. Increasing this voltage of 11,000 to 25,000, involves the subject of cables, etc., and requires very careful working out in order to determine whether or not there would be real economy in the increased voltage. For transmitting smaller amounts of power to greater distances, it is my opinion that

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the most popular method for some time to come will be the low-voltage generator with step-up transformers.

In regard to possible size of steam turbines, I think that units of 25,000 kw. are even now within reach. The steamships Lusitania and Moritania, now building on the river Clyde, will have steam turbines as their motive power, the turbine units to be something like 30,000 h.p. If such machines can be built for steamship service, they are, of course, available for the driving of electric generators, and generators of this capacity will without doubt be developed commercially as soon as there is a real need for them.

W. S. Murray: In matters of this kind cost must ever enter as an important factor. Though it may be possible, by a combination of the generators and transformers, to equip a generating plant for the same money as that required to pay for generators without transformers, yet it seems to me that such a combination should not be considered until necessity makes its development imperative. Also, there is no doubt but that in creating high voltages in a generating apparatus, the active conductors of which are limited to a few coils, there is also created very poor regulation. High-voltage apparatus will therefore drive the designer from well-distributed windings to coil-wound armatures.

I wish to support Mr. Skinner's statement in regard to the protection of the station by means of transformers. If there are great transmission distances, naturally the voltage has to be increased, and under these conditions there is no better lightning protection than well-designed step-up transformers.

Though Mr. Behrend contends that the repairs on transformers are rather difficult to make, still it should not be forgotten that the cost of equipping a step-up station with spare transformers is much less than that of equipping a station with spare generators.

My conception of a well-designed high-voltage power house—by high voltage I mean 20,000 volts or more—is that of a fort, the ramparts of which are the transformers; they take most of the hard blows. It is not necessary to compare the damage by lightning in a plant having transformers between the generator and the line with a plant that is not equipped in this way.

In view of the fact that the generator-transformer combination affords better lightning protection, I admit that I shall remain heartily in favor of step-up apparatus until a real case is made out for high-voltage machines.

A. H. Armstrong: The design of any type of apparatus must be governed by commercial demands. Generating and transmitting systems may be divided into two broad classes; those centering in and about large cities and operating at from 6,000 to 11,000 volts, and those having an unlimited area of distribution calling for potentials of 33,000 volts, 44,000 volts, or higher.

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Mr. Behrend would have us believe that the choice of transmission potentials is dictated by the limitations of generator design and that the installation of 5,000 and 10,000 units offers the opportunity for higher generator potentials, and hence permits the adoption of higher distributing potentials in and about cities. I cannot take this view of the matter, as the potential of city distributing systems is limited by other considerations than those of machine design. To substantiate this statement I would point out that the generators with highest voltages are not the large units used in city generating stations but the smaller units used in interurban railway and general power distribution systems. The manufacturers are perfectly willing and able to build generators for higher potentials than 11,000 volts, but the fact that low potentials are still adhered to in city distributing systems bears out my statement that the potential of such a system is dictated by questions of reliability of cable distribution and the general needs of the distributing system rather than by any inability or unwillingness of manufacturers to construct machines for 15,000 or 20,000 volts.

While generators may be wound for 15,000 to 20,000 volts, these potentials fall far short of the requirements of a general distributing system outside of large cities. The history of such distributing systems indicates a tendency towards large generating stations feeding over considerable areas at the highest practicable potential; and the potentials required are so much in excess of what can be accomplished in generator design that it would seem, considering the transmission problem broadly, that the low-potential generator used in connection with step-up transformers must continue to be considered the best engineering.

Furthermore, both railway and general transmission systems are constantly expanding over increased areas, and the history of such systems has been to call for a much higher potential than that adopted in the original installation. The flexibility provided by low-voltage generators and step-up transformers takes care of the needs of the expanding system, while it is very probable that a high-voltage generator wound for the original transmission potential would ultimately be used in connection with step-up transformers.

W. L. Waters: The best answer to an inquiry as to the practicability of large alternators wound for 20,000 volts is that such alternators have already been built and are in operation. I would modify somewhat the history of high-voltage alternators from that given by Mr. Behrend. The first high-voltage alternators were the 10,000-volt, 1000-kw. Deptford alternators built by Ferranti in 1889. Then in 1897 came the 15,000-volt, 1800-kw. Paderno alternators built by Brown Boveri, and then in 1900 came the 20,000-volt, 1050-kw. alternators built by Schuckert for the Valtellina line.

The practicability of building high-voltage alternators depends entirely on the nature of the workmanship put into them.

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The design of such alternators is similar to that of 6600-volt alternators; the only point for the designer to take care of is to make the work on the armature winding as easy as possible for the shop. After this is done, it is altogether a question of careful and skilful work in the armature-winding department. The larger the output of the alternator the easier it is to make a satisfactory high-voltage armature coil, as the conductors per slot are fewer and they are of larger section and consequently more rigid. It is only with alternators of small ampere capacity that serious difficulties arise.

Mr. Behrend mentions a 150-kw. 22,000-volt alternator which has been in operation for sometime. Mr. Behrend is not particularly specific as to the conditions of load under which this machine has been operated. As far as can be seen from the paper, this machine was operated under a steady synchronous motor load. This is not nearly so severe a test as that where an alternator is continually subjected to sudden variations in load, heating and cooling, being taken off and thrown on the line, and possibly short-circuits. It is quite possible that Mr. Behrend would have a different experience with that alternator if it were operated in some small power station on a high-voltage line.

Breakdowns of the insulation to ground or between phases rarely happens. On high-voltage alternators, breakdowns virtually always start as short-circuits between the individual turns of a coil. In regard to their liability to such short-circuits between conductors in the same coil, it is my experience that there is very little difference between 6000-volt alternators and those of higher voltage. These short-circuits are apparently caused partly by sudden surges on the line, and partly by the gradual deterioration of the insulation due to the vibration of the individual conductors in the coil. This gives as a first requisite of a high-voltage alternator, that it must have the insulation on each conductor as good and as permanent and as strong mechanically as possible, and that the conductors must be held perfectly rigid both in the slot and outside. This practically means the abandonment of the scheme of threading the conductors through a closed insulating tube. Though this construction has been standard in Europe for high-voltage work, and has been used to a certain extent in this country, I think we shall find that it will gradually be abandoned in favor of the form-wound and subsequently insulated coil for all high-voltage work. It is almost impossible to make a perfect high-voltage coil out of small wires, such as would be used on a 150-kw. 22,000-volt machine, as such a coil could not very well be made sufficiently rigid to last any length of time. For this reason I think that about 30 amperes is the maximum current capacity for which high-voltage alternators can be constructed; with very careful shop work, 30-ampere alternators can be constructed up to 30,000 volts. With steam-turbine alternators there are

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liable to be extra difficulties on account of crowded space available for the end-connections, but this crowded space is chiefly due to the demand for small floor space for these alternators, and extra space will probably have to be allowed for 25,000-volt machines. If this were done, there would be no more difficulty with a steam-turbine alternator than with any other alternator of like capacity.

The demand for such high-voltage alternators would practically be limited to systems operating with 20,000-volt lines. If such a system were of comparatively small capacity and operating on overhead lines, 20,000-volt generators would hardly be desirable, as the supervision would probably not be of the best and the danger of operating directly on a overhead line would be too great on account of possible lightning troubles, so that probably in this case the usual system of a low-voltage generator with transformers would be used. For large city power system work, there would be undoubtedly a certain demand for such generators, especially as 20,000-volt cables are now in use. In such a case, a 20-000,volt generator would be somewhat simpler than a low-voltage generator and transformers, and probably somewhat cheaper. If a demand for such 20,000-volt alternators does arise, I think that they can undoubtedly be manufactured to operate as reliably as 6000- and 12,000-volt machines.

H. G. Stott: Mr. Behrend's able and suggestive paper upon the characteristics of high-tension generators raises the point for discussion of whether we need them or not. I believe that the ultimate solution of this matter lies, not in the generator, but in the question of how far we dare go in voltage in underground cables.

With high-tension transmission, oil-cooled transformers are now invariably installed in all cases where the voltage is above 20,000, as the advantages to be gained by the oil acting as insulation are now fully recognized by all.

The transformer as a piece of lightning protective apparatus is a most important consideration, as very few cases are on record of generators being injured by lightning when transformers were interposed between them and the line. If a transformer were destroyed by lightning, it could be cut out in a few minutes, whereas if a generator were struck, the repairs to it would cover several days.

Professor Ryan's classical paper, read before the Institute two years ago*, showed that owing to the concentration of electrostatic stress on a conductor, there was a limiting diameter of copper for each voltage, below which it is not safe to go; so that unless very large quantities of power are to be transmitted, nothing is gained by increasing the generator voltage.

The limit of generator voltage would thus seem to be determined by considerations entirely outside of the machine itself.

* "The Conductivity of the Atmosphere at High Voltages," by Harris J. Ryan. TRANSACTIONS A. I. E. E., 1904. Vol. XXIII, p. 101.

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Percy H. Thomas: The practicability of 22,000-volt generators must evidently depend largely upon their capacity and also upon the speed and other features of the design which will be determined by the conditions of the plant. What can readily be done in generators of the size and type of those in the Interborough Rapid Transit Company's 59th street power house, is hardly practicable in a small generator requiring fine wire windings.

Although the high-tension generator eliminates transformers and some switches, and perhaps switchboards, it has the disadvantage in parallel operation that all high-tension lines must be electrically connected; whereas with low-voltage generators and step-up transformers, paralleling may be done on the low-tension bus-bars, thus electrically disconnecting the high-tension circuits from one another where found convenient.

The importance of this point must not be overlooked. Further experience with large high-tension systems will probably demonstrate that a material increase in reliability of operation will be obtained by maintaining electrically separate the naturally separate divisions of the transmission system. For example, where power is transmitted over different routes to the same sub-station, or to an entirely different sub-station, no limitation of capacity will result by paralleling on the low-tension, if as is usual the capacity of a single line is equal to that of one or more groups of transformers. By this arrangement, the direct effect of lightning discharges, grounds, and short-circuits occurring in one of the separate lines is practically nothing on the others; with the present frequent paralleling of the whole system on the high-tension, however, each high-tension disturbance of a severe character equally endangers virtually all of the transmission system.

A good example of the seriousness of this condition is the accident and shutdown described by Dr. Steinmetz before the Asheville Convention, in 1905. In this case a large electrical railway plant operating all its high-tension apparatus from a common bus-bar was shut down for a considerable length of time by several simultaneous failures of cables and other apparatus, presumably all resulting from a single break. This system had high-tension generators; had it been supplied with low-potential machines and step-up transformers and had each sub-station been operating independently on its high-tension lines, or had it been otherwise possible to obtain this electrical independence, it is very likely that this breakdown would have involved only the sub-station in which the original break occurred, leaving the road perfectly able to operate its entire system. I do not mean to express the opinion that under all conditions this is sufficient reason for foregoing all the advantages of high-tension multiple operation or high-tension generators, but simply to say that I believe this condition must be taken into

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account and that actual experience with high-tension plants is such that it should receive considerable weight.

The matter of insulation must receive the most careful attention in high-voltage generators, not only insulation between windings and core and between overlapping coils of different potential, but between turns of windings especially near the leads. The concentration of potential on the outer turns of a transformer connected to a line subject to "static" is well known. This same condition must, of course, exist in a high-tension generator connected to such a line, and in most cases substantial protection or sufficient insulation between turns is much more difficult to obtain. For instance, the peculiar shapes of the armature coils found necessary for mechanical reasons, renders it difficult to get the high insulation strength between adjacent wires or layers. In view of the inductance of these coils and the capacity of the windings of the core, there will always be a strong tendency for static disturbances to pass between turns in such coils. The chances that such static puncture will result in a short circuit supported by the generator electromotive force are exceptionally good. It is often said that additional insulation may be used in the coils nearest the line to meet this danger; this method is generally impracticable, however, since the increase in strain upon these coils is not of a reasonable magnitude, say two or three times, but may be ten or twenty times the normal strain. The conditions rapidly become more severe as the voltage rises. Personally, I believe that usually on the higher voltage machines the only practicable solution is in protective apparatus. As a matter of actual experience, the short-circuit of coils of high-tension generators connected to lines, except in favorable conditions, such as are often found in very large 10,000 generators, is a serious handicap.

On the other hand, it is usually found that the numerical constants, involving the number of turns and exposed surface of the coil, are such that a choke-coil will be much more effective in protecting a high-tension generator than it will in protecting a high-tension transformer. In many cases it is likely that a static interrupter will be found more economical in space and cost than an equally powerful choke-coil.

It is an unfortunate fact, borne out by examples in actual service, that the short-circuiting of an end-coil in a high-tension generator operating on a transmission line throws the original strain, possibly only slightly reduced in intensity, directly upon the second coil, which will then often break down, and the third coil will in turn be subjected to similar conditions, etc. I have in mind one case where such a discharge passed across coils all the way from one generator lead to another, the marks being traceable in nearly all the coils. In many cases there were pittings of the wires showing the following of current sustained by the generator.

I wish to urge strongly the importance of protecting against

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the unusual susceptibility of a high-tension generator to short-circuits between turns of the end-coils, when subjected to static strains. A single breakdown in a generator disables the whole machine, whereas one of a group of three transformers in delta may be spared without serious inconvenience.

Philip Torchio: Not long ago I happened to deal with a large water-power proposition in which the conditions seemed to warrant the use of 22,000-volt generators, as the total length of the transmission line was about 15 miles, with a total capacity of 30,000 to 40,000 kilowatts. Manufacturers were asked to make a preliminary study for machines of 2250 kw. 25,000 volts, 3-phase, 60-cycle, 112.5 rev. per min. Under these specific conditions it was found that the costs and efficiencies of generators of different voltages would be approximately as follows:

Voltage of alternator	Relative cost	Relative efficiency
2,300	100%	96%
15,000	130%	95.25
25,000	155%	94.20

From the above it would appear that as far as cost and efficiency are concerned, there would be hardly any difference between the low-voltage generator with step-up transformer and the 25,000-volt generator. On the other hand, if step-up transformers are used, great savings can be made in the copper and transmission line by raising the voltage higher, say, to 44,000 volts, which can now be made as entirely safe to operate as the lower voltage, and probably, in connection with oil transformers, safer than with 25,000-volt generators.

The selection of generator voltages is usually determined by the conditions of distribution. Lighting companies have usually been conservative and seldom exceeded 6600–9000 volts. Electric railroads, on the other hand, have adopted 11,000–13,000 volts, but in most instances the extra insulation on cables has almost entirely offset the reduction in their copper cross-section. I think, however, that with proper grading of insulation on cables, one can now get greater economy from higher voltages then have been heretofore realized.

Aside from these considerations, if we are unhampered by any restriction, the problem of selection of voltage simmers down to the question of cost of cable wiring and switch-gears at the station, as with large generating units the problem becomes rather troublesome if great amounts of current are to be handled in the station. One will readily appreciate these difficulties if he considers that a 20,000-kw. generator with 50 per cent. overload would require switches of about 8,000 amperes' capacity at 2,200 volts. If, however, 12,000 volts are used, 1500-ampere switches can be substituted with the overall dimensions practically unchanged. If the voltage should be

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doubled the current would be halved, but the difficulties and costs would be greatly increased in getting the proper insulation on cables and the proper spacing of the high-tension switch elements.

Offhand, I would say that in large central stations these considerations would prohibit the use of high-voltage generators. The above applies to large units.

In the case of smaller units I should think the conditions would not materially change the above conclusions.

In connection with high-voltage generators, it may be interesting to mention the fact that Italy was among the first to use high-voltage generators with their water power transmission plants. The Paderno installation was designed between 1895 and 1896, using 2,200-h.p. Brown Boveri units wound for 15,000 volts. Later the Valtelina three-phase railway installed three 1,500-kw., 22,000-volt, 3-phase, 15-cycle, 150-rev. per min. Ganz generators, wound for star connection and tunnel winding. This and other plants have been operated for many years, and I believe that were it not for the difficulties of installation inherent to the type of slot, the service would have been considered satisfactory. With this type of winding the greatest drawback is the length of time that is required to replace a burned out coil. The explanation for the favor of high-voltage generators in Italy lies, in my opinion, in the fact of the relatively short length of transmission lines and the multiplicity of distributing lines, making desirable the use of a moderately high voltage, which happened to be very close to the commercial dividing line between direct-wound generators and generators with step-up transformers.

F. V. Henshaw: In connection with high-voltage, air-cooled transformers, will Mr. Torchio say if he has any information of any case of deterioration of the insulation due to ozone, or chemical action resulting from brush discharge.

Philip Torchio: With a certain type of coil, insulated in a certain manner, from experience with moderately high voltages covering a great number of units operated for many years without breakdowns of any kind except due to mechanical injury, I would take my chances with 20,000-volt coils; I would not bother about the ozone. With some other insulation, I would not take chances with 2200 volts.

C. F. Scott: I have just made some general calculations to determine the field of application for generators of 150 kw., wound for 25,000 volts. The distance of transmission will ordinarily exceed 25 miles, as a less distance would not necessitate so high a voltage. If No. 6 wire be assumed as the smallest convenient practical line wire, we will find that the cost of the transmission line will approximate, say, $25,000. It is desirable, therefore, that such a line transmit considerably more than 150 kw. in order that the cost of the line per kilowatt will be small. Moreover, such a line will transmit 150 kw. with a loss of only

about one per cent. Such a line, therefore, has a capacity for transmitting 1,000 kw, or 1,500 kw., and, if this amount of power is to be generated and transmitted, it will usually be advantageous to use a few large machines instead of many small ones. In other words, 150 kw. is too small a unit for the generation of power at 25,000 volts. The application of generators of this kind, as has already been pointed out, would be quite special.

Paul M. Lincoln: What capacity would the generator have if wound for 2200 volts instead of for 22,000 volts, with a regulation of from say, eight to ten per cent?

I agree with Mr. Stott that the oil used in transformers is of great advantage, and enhances the desirability of the transformer combination over the high-voltage generator. Oil has the property of automatically healing insulation ruptures, and for that reason I believe that such a combination would be much freer from lightning troubles than would a high-voltage generator. Another thing that operates against the high-voltage generator, particularly one of good regulation, such as the one mentioned in the paper, is the liability of the winding to bend on sudden short-circuits. The reasons for this are two: first, on account of the turns being many and the wire therefore necessarily thin and weak; secondly, the good regulation causes a much larger rush of current on such a short-circuit, thereby making the bending forces the greater.

B. A. Behrend: I think that my commentators are laboring under the impression that I had chosen the title of this paper for the purpose of advocating broadly the use of 22,000-volt generators for all sorts of purposes. Let me say, therefore, that the subject of this paper was assigned to me by the chairman of the high-tension Transmission Committee, who, knowing perhaps that I am something of a wolf in the fold and might start some discussion, suggested the title of this paper.

Mr Skinner is well known for his good work on insulation, but I confess that I should have relished Mr. Skinner's remarks better if he had, for the time being, forgotten that we are not connected with the same business interests.

Turning, now, to the technical statements in Mr. Skinner's remarks I must say that I really concur with him in everything he has said except the mode in which it was put. Regarding the point already raised by Mr. Mershon and brought up by Mr. Skinner, concerning the relative cost of the apparatus in question, Mr. Torchio has cited an interesting case. Mr. Mershon requested me to give a comparison of prices and, therefore, I sent an inquiry to our sales department with the following result. A 200-kw., 2200-volt 3-phase, 600-rev. per min. generator with three 75-kw., 2200-volt to 22,000-volt. transformers would be sold for $3,849.00. A 200-kw., 22,000-volt, 3-phase, 600 rev. per min. generator would be sold for $3,837.00; the difference is only $12.00 between the two plants. The total shipping weight of the 22,000-volt generator is 31,000 lb., whereas the shipping

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weight of the combination of generator and transformers is 30,650 lb. Freight charges, therefore, would not seriously interfere with the sale of these machines in far-off districts.

Mr. Skinner and other gentlemen have imputed to me the statement that the voltage of the generator should determine the line voltage; what I did say was that it was the external conditions, the amount of power to be distributed, the area of distribution, and other conditions that determine the line voltage. If the line voltage thus determined happens to be such that the generators can readily be wound for it, the omission of the transformers may seriously be considered.

Mr Skinner referred to the question of money tied up in spare parts. I can argue on this only academically but, as this paper has been written for the purpose of " raising the dust "—in the laying of which we are concerned in this discussion—I may as well raise some more dust. I stated that the carrying of spare parts and the repairing of the generators was a comparatively inexpensive and simple matter. If a single coil breaks down, a repair can often be quickly made by bridging over and cutting out the injured coil. In a small power plant the carrying of a few spare coils is no worse than the carrying of a spare transformer.

I distinctly said, in reading my paper, that 20,000 volts need not be used for distribution in a city of the size of New York; the amount of power and the area of distribution are not great enough. The population of New York will have to be increased before 20,000 volts will be needed on our generators! 11,000 volts is perfectly satisfactory for the area that has to be covered in this city. At the present time, there are no cities large enough in this country to justify a higher potential. But twenty-five years hence the population of New York will be at least doubled, and then the problems which we are now discussing in an academic way will have become actual problems, unless a widely different system should be discovered or invented.

Mr. Murray agreed with Mr. Skinner so thoroughly that I need not reply in detail to his remarks. But I want to say one word or two about a statement that he made three times: he called the 22,000-volt machine, to which I have referred in my paper, " a very very poor piece of regulating apparatus ". So, then, 4 per cent. regulation is " very very poor "! Four per cent. regulation can not be got at all with transformers and low-voltage alternators designed for 8 or 10 per cent. regulation!

Mr. Armstrong said that " Mr. Behrend wants us to believe " that generators should be wound for 22,000 volts and that this voltage, therefore, should be used for distribution and as line potential. And then he proceeded to show that this statement, which I have never made, is absolutely wrong. I referred, while reading my paper, to the power plant in which Mr. Mershon is interested at Victoria Falls of the Zambesi River. The distance from Victoria Falls to the South African mining district is about 600 or 700 miles. The transmission line will be operated

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at a potential of 100,000 volts or more, and it goes over the heads of Kaffirs and lions, and one certainly would not select generators of 22,000 volts for this transmission line. I thought that I was speaking to experienced electrical engineers who were fully conversant with all these conditions, and I thought that Mr. Armstrong would hardly be misled to believe that the potential of the generators determined the line potential. But I also stated that the conditions external to the power plant determined the choice of the voltage of the generators. A competent engineer must be able to see more than merely the generating plant; he must have a grasp of the conditions of the entire system, including the transmission line and the conditions of distribution and utilization, as these determine the choice of the line voltage and the voltage of the generators.

I heartily endorse Mr. Waters' remarks. Good shop work must be put into high-voltage machines, and there is no use in denying the fact that it is difficult to obtain thoroughly reliable workmen to whom such work can be safely entrusted. Here lies one of the chief difficulties connected with the building of high-potential generators. Mr. Waters is right that good workmanship on high voltage coils is of the utmost importance.

Mr. Stott's remarks contain statements which I should have included in my paper. He emphasized the fact that the insulation of the cables at present forms one of the chief obstacles to an increase in the generator voltage in large power plants. I am completely in accord with Mr. Stott in regard to the great advantage obtained from oil used as an insulator. It has been proposed to use oil for insulating the stator of electric generators for high potential. This appears feasible but, at the present time, I should prefer to instruct our sales department to quote rather high prices on such oil-insulated generators.

Some one has asked about the wave shape of the generator described in this paper. I have not yet had an opportunity to determine the wave shape by means of an oscillograph, but I hope to do so later. The generator which was used for 22,000 volts was a stock machine having the same number of slots as that used for potentials varying from 10,000 to 15,000 volts. There are many machines of this type and size in operation both as generators and as synchronous motors, operating on short and long lines, and there has never been the least trouble with these machines and certainly no trouble due to wave shape.

It was stated that the manufacturer preferred to sell the generator and the transformers rather than the high-potential generator by itself. This point was also raised by our sales department; they were afraid that they would be overrun with orders for 22,000-volt generators, but I assured them they would get none.

Mr. Thomas made some most interesting remarks on the subject of lightning protection, as might be expected from this thoughtful source. I well remember how he called attention

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several years ago, in his excellent paper before this Institute, to the fact that the strain increases between the end layers of a transformer coil, and, of course, it does likewise in the coils of alternators and synchronous motors. In the discussion of Mr. Thomas' paper,* I showed mathematically and graphically, by the use of Fourier's analysis, this increase in strain—and I want to say, in this connection, that we are always careful in the insulating of our coils to look out for the stresses between layers—I believe that it is quite feasible to insulate individual conductors in the coils closest to the terminals in such a manner that a breakdown from this source is not likely to occur. Mr. Thomas also called attention to the use of choke-coils in connection with lightning protection. Mr. Thomas knows a great deal more about lightning protection than I do, yet I wish to state that in Switzerland and northern Italy, where plants located in the mountains are subjected to considerable danger from lightning, insulation of the frame of the generator is resorted to as a means of lightning protection. Generators and motors are mounted on porcelain insulators and, while this may not appear a very mechanical construction, it has proved an excellent protection against lightning.

Mr. Torchio has stated a case of 2,200-kw. generators wound for 22,000 volts, on the one hand, and wound for 22,000 volts with transformers on the other, and he has remarked that the prices which have been quoted him by different manufacturers for these different types of plant were almost exactly the same. This bears out the statement made by me in this discussion, that there is but little difference in the relative cost of high-voltage generators, and of low-voltage generators and transformers. Mr. Torchio has also called attention to the difficulties at present connected with the use of high-potential cables. I am in thorough accord with what he has said on this subject.

Mr. Scott has asked me where such machines would be used. I have said in this discussion that there are a number of small plants of 300 or 500 kw., in which 22,000 volts would be a satisfactory line potential and, in this case, by winding the generators for 22,000 volts, a considerable simplification of the power house may be obtained. There is also little force to the argument that the manufacturers will refuse to build 22,000-volt machines, as they are special. We actually took a standard 12,000-volt machine, and wound it for 22,000 volts.

I am in accord with Mr. Scott in regard to his statement that some engineers recommend the same system under all sorts of conditions. There is no panacea for all the troubles that are encountered in our work, and I am glad to find Mr. Scott among those who advocate the taking of a broad view, though I fear that Mr. Scott and all the rest of us will be in our graves when

* Static Strains in High-Tension Circuits, and the Protection of Apparatus," by Percy H. Thomas. TRANSACTIONS A. I. E. E., 1902. Vol. XIX, pp. 213–276.

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engineers are still persisting in advocating a specific system for all conditions.

W. S. Murray: Does Mr. Behrend really mean that on the high-voltage machine, notwithstanding the fact that the distributed winding must be dispensed with, that the regulation will be as good? If conductors are bunched will there not be a much larger percentage in regulation? Is Mr. Behrend willing to say that he expects this regulation to be just as good without the distributed winding? Regulation is one of the most important things in the design of large transmission plants, and it cannot possibly be overlooked.

B. A. Behrend: In answering Mr. Murray's question, I should like to state the facts. Comparing with one another, a generator having one slot per pole per phase, a generator having two slots per pole per phase, a generator having three slots per pole per phase, a generator having five or six slots per pole per phase—all cases with which I am thoroughly familiar through my own personal experience in designing some million or more kilowatts of such generators—I must state that I have been unable to notice, in spite of most carefully carried on experiments, any appreciable difference in the regulation of these machines. There ought to be, and there probably is, a slight difference in the regulation, but it is too slight to be established with certainty. The armature reaction is less in the generator having few slots, while the self-induction caused by local fields in the armature winding is greater. Thus, the theory of armature reaction shows that below saturation there is no difference in the regulation, while at high saturation there is a slight difference in favor of the machine having many slots. We have a number of generators and synchronous motors operating in parallel with different numbers of slots per pole per phase, and certainly no difficulty has ever been experienced on that score.

W. S. Murray: I understand that it is not entirely a question of self-induction—it is the result of the two. Does Mr. Behrend feel that his remark—that his conclusion—is applicable to very large units and also generators wound for single-phase transmission? That is that 20,000-volt generators will give as good regulation as distributed-wound generators?

B. A. Behrend: To answer Mr. Murray's question I would say that the regulation is practically the same in both cases, understanding by regulation the voltage drop between no load and full load. I have had no experience with single-phase railway work, but I should say that it will be necessary to avail oneself of all possible advantages by designing a generator so as to give as nearly a sine curve as possible, so as to make it as easy as possible for the single-phase motors. Advantage should be taken of everything to make it easier for the single-phase motors.

W. S. Murray: Does the remark of 4% regulation apply?

B. A. Behrend: There should, of course, be good regulation in a single-phase railway plant on account of the large wattless

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currents. But this regulation depends rather on other factors, as the reluctance of the magnetic circuit, the amount of excitation, than on the number of slots per pole per phase.

Ralph D. Mershon: I hope that Mr. Behrend later on will give us some cost and efficiency figures for such generators as compared with lower voltage generators combined with transformers, as I believe he has such figures at hand.

I was rather surprised to hear Mr. Skinner lay so much stress upon the question of lightning protection. From what I know of his attitude relating to choke-coils, I should have expected him to assume that enough choke-coils would be used in series with the generators to protect them. Contrary to Mr. Stott's experience, I have known of several cases where generators having step-up transformers between them and the line were damaged by reason of lightning discharges. I have known such trouble to occur without any apparent damage to the transformer. In such cases the static discharge which damaged the generator was probably induced in the low-voltage circuit of the transformers by the electrostatic inductive action between the windings of the transformers. In some cases, however, there may have been a break down between the high- and low-voltage windings of the transformers which breakdown repaired itself by reason of the healing action of the transformer oil. I think there is, unquestionably, a place for the high-voltage generator, and this paper of Mr. Behrend's is very timely. I have listened to it with a very great deal of interest indeed, and will receive with even more interest the cost and efficiency figures previously mentioned which I understand he will give us later on.

F. G. Baum (by letter): I take exception to the statement that hydraulic units of or above 7,500 kw. are not to be considered of importance at present. Several installations are under way for hydraulic units of 7,500 and 10,000 kw., and by putting a turbine on each end of the generator shaft, there may be produced units as large as 15,000 kw., or even 20,000 kw.

The disadvantages of winding for a high voltage are:

1. Increased losses.
2. Increased cost.
3. Decreased capacity.
4. Increased danger and risk of breakdown.

The advantage is that reduced space is required, as no transformers are necessary.

In some localities the question would be answered by the cost of space, but, eliminating the space-factor, it does not seem advisable to wind for 22,000 volts. At some point it is folly to increase the voltage on generators. I am inclined to the opinion that this folly point is reached in most cases before 22,000 volts is attained.

Ernst J. Berg (by letter): I quite agree with Mr. Behrend that large turbo-generators lend themselves best to very high voltage windings. At the same time it may be of interest to

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know that one manufacturing company has built 18,000-volt alternators directly connected to slow-speed engines.

The transmission line voltage has, in my opinion, a bearing on the best generator voltage, since with one of the high-potential lines grounded in a delta system, high static stresses are induced in the generator windings. These do indeed occur even in a grounded star system when power is conveyed over two of the lines and the ground used as a third conductor.

Therefore, it is evident that it is not well to make the generator voltage too low in reference to the line voltage. My judgment would be that it ought to be not less than one-sixth or one-fourth of the line voltage, corresponding to 16,000–25,000 volts in a 100,000-volt transmission system. Judging from the amount of insulation required in transformers, the limit would seem to lie somewhere between 20,000 to 25,000 volts, provided alternators of reasonable wave shapes are demanded.

W. J. Foster (by letter): The question of practicability involves construction cost and efficiency. It may be said that the question of construction is wholly one of insulation. Is it possible to allow the space necessary for the insulation and so to apply it as to insure against breakdowns? This may be answered in the affirmative, with the qualification that large slots are always possible where the pole-pitch is large. Hence, there are certain sizes of generators that are well adapted for such high potentials. It is probable that the simplest way of putting this matter above a certain minimum size is to make the output per pole the criterion, since this eliminates to some extent the consideration of periodicity. It is probable that almost any generator with a capacity of 1000 kw., or more, whose output per pole is at least 100 kw., can be advantageously wound for 22,000 volts. All steam-turbine generators up to 60 cycles belong in this class. There is another type of generator that is admirably adapted to 22,000 volts; namely, the large engine-driven fly-wheel type. Such generators have a large pole pitch, and, consequently, make it possible to select the number of slots that permit of the necessary room for insulation between winding and core. They also make the high-potential machine desirable by reason of the fact that a large percentage of their cost is due to the mechanical parts. Hence the additional cost of the high-potential machine is generally less than the cost of step-up transformers. It is frequently much less. Furthermore, the efficiency of such a generator is much higher than the combined efficiency of the low-potential generator with step-up transformers.

The synchronous motor in motor-generator sets and frequency-changer sets in sizes of 1000 kw. or more, may often most advantageously be wound for 20,000 volts. The majority of these are for low frequency, such as 25 cycles, and for use in sub-stations to drive direct-current generators or alternating-current 60-cycle generators. Winding for 20,000 volts will frequently simplify the sub-station by eliminating step-down transformers;

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at the same time it will invariably increase the efficiency of the transformation.

I wish briefly to describe some 5000-kw., 50-cycle, 100-rev. per min. engine-driven, fly-wheel type generators that have been constructed to operate at approximately 20,000 volts, three-phase. The ampere rating of these generators corresponds to a normal potential of 18,000 volts, but the specifications require them to be capable of operating at a maximum of 22,000 volts. Three of these generators are being installed in the plant of the Pacific Light and Power Co., Los Angeles, California.

Floor space required	31 ft by 6 ft. 9 in.
Diameter of stator	28.5 ft.
Diameter of rotor	25 ft.
Radius of gyration	8.8 ft.
Weight of rotor	186,000 lb.
Weight of stator	162,000 "
Weight of accessories	12,000 "
Total weight	360,000 ".

The armature coils have stood a high-potential test of 40,000 volts for one minute.

The commercial efficiency is as follows:

1.25 load	96.5%
Full load	96.2%
0.75 "	95.2%
0.50 "	93.5%
0.25 "	88.0%

The class of generators which will undoubtedly make the best showing in the matter of cost to the customer is the large fly-wheel type of low periodicity, such, for instance, as a 25-cycle, 5000 kw., 75 rev. per min. Such a generator wound for 22,000 volts, will not cost the customer more than 15% above the cost of the generator wound for the most advantageous potential with step-up transformers. Step-up transformers will cost about 30% of that of the generator. Hence there is a saving in the initial cost of the apparatus alone of from 10 to 15%. To this should be added the saving in the station due to the elimination of space for transformers. Along with this saving in the initial cost there will accrue to the consumer a continual revenue due to the better efficiency. This will amount to at least 1% at full load and 1.5% at one-half load. Many large water-wheel driven generators might well be wound for 22,000 volts where it is desirable to use that potential on the transmission lines. It would be an interesting study to work out the cost and efficiency of such generators for transmitting Niagara power to Buffalo in comparison with the use of generators with step-up transformers, as at present. There is no doubt in my mind but that a most decided gain would be shown. The 3750-kw. generators on the American side and the 7500-kw.

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on the Canadian side are ideal machines for 22,000 volts, by reason of their large capacities and the relations that exist between capacity and the number of poles.

In conclusion, after several years' experience in designing, I am confident that 22,000-volt generators properly selected in the matter of their ratings, offer less difficulties in design and construction than numerous 6,600-volt generators now in operation.

R. S. Kelsch (by letter): In June, 1905, the writer endeavored to purchase 25,000-volt, 3750-kw. generators for a hydroelectric development to consist of five 3750-kw. generators for an 18-mile transmission. Several large companies manufacturing this class of electrical apparatus were asked if they would construct such machines. One company replied that they did not think it feasible; the other companies thought it feasible but were not prepared to supply machines of this voltage at that time.

The plant referred to is now operating, using 3750-kw. generators, step-up transformers, etc. In preparing plans for this installation, and while considering 25,000-volt generators, the following points, for and against the use of such generators, received consideration:

Extra cost. Generators; potential transformers; current transformers, etc.

Saving. Saving of step-up transformers, building for transformers, generator cables, entire low-voltage bus-bar system, switches, etc., the water- and oil-pump system, insurance on transformers and building, interest, and depreciation.

Disadvantages. The 25,000-volt generators would be exposed to line strains, lightning, etc. In case of lightning entering the station, liability of greater damage and serious interruption to service, which might be overcome by extraordinary insulation on generators, and 25,000-volt bus-bar constructed to have had capacity to dissipate abnormal strains.

There is also the disadvantage that with such generators the multiplicity of voltages sometimes required for the high-tension systems could not be obtained as readily as with the step-up transformers.

Advantages. Advantages obtained by using the 25,000-volt generators are; better regulation, simplicity of station wiring, reduced fixed charges, reduced danger from fire due to the absence of oil-cooled transformers.

In Montreal there is one hydroelectric plant containing eight 750-kw., 4400–5000-volt generators, working direct on the transmission lines. In nine years' service there has not been one case of trouble on the high-tension windings of the generators, due to lightning or other abnormal strains. And this plant has yet to record the first injury to an employee or any other person from these 5,000-volt machines.

When this plant was installed, the specifications for these generators called for the insulation to be such as successfully to withstand a 25,000-volt alternating-current breakdown test.

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The writer believes that a plant containing a large number of 25,000-volt generators can be successfully and safely operated.

L. Schüler (by letter): There is no doubt that alternators can be wound for pressures over 20,000 volts. As early as 1895 I assisted in the design of a 30-kw. 27,000-volt machine, which was built by the Allgemeine Elektricitats-Gesellschaft, Berlin. It worke[illegible]factorily. The coils were embedded in troughs of micani[illegible] the machine was made for the purpose of showing that th[illegible] possibilities of this new (at that time) material.

Another question is, whether it is advantageous to use such machines in connection with long transmission lines; this I think is *not* the case. Mr. Behrend is quite right to advocate the carrying of spare coils, but it should be well understood that it takes at least a couple of hours to replace coils of an alternator, while practically no time is required to switch in a spare transformer. Even if no spare transformer is available, in case of a breakdown it will very often be possible to carry the load on the other transformers while the broken down one is being repaired. The overload capacity of alternators, and especially prime-movers, is usually not sufficient to do this.

As Mr. Behrend says himself, there would not be much saving in costs by the adoption of such extra high tension generators, I think it would be rather unwise for supply companies to use and for manufacturing companies to sell them.

Farley Osgood (by letter): Without question the operating dangers in a high-voltage machine are greater than in a machine of moderate voltage. The greatest objection the writer has to a machine wound for such a voltage is the uncertainty of protecting it from outside disturbances such as grounded or short-circuited lines, lightning discharges, etc. With step-up transformers, a defence-wall for the generating units is maintained, and the protection afforded is in my opinion worth the additional cost.

No doubt such a generator can be built and will run satisfactorily, but I think that the discussion would finally resolve itself more into one of practical operation rather than electrical or mechanical possibility. As an extreme case, Mr. Behrend cites as possible a 20,000-volt machine as small as 150 kw. capacity; such a machine would of course be built for experimental purposes only, as there is hardly any power problem which would require such an unusual piece of apparatus.

It seems to me that a machine wound for 20,000 volts to be used directly on the power system should receive consideration only where units of enormous capacity are required and where the transmission distance is very short.

H. F. Parshall (by letter): The practicability of winding generators for 22,000 volts would depend largely on the size of the machine. In the case of the proposed installation for the London County Council, where 12,000 to 15,000 kw. turbo-generating sets are in contemplation, the matter was the subject of most careful

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consideration, the result of which was that 15,000-volt generators were considered practicable and that they would be more satisfactory in practice than low-voltage generators with step-up transformers. Voltages higher than 15,000 were considered, both in the generating and transmission systems, the transmission system in this case being underground and thereby being subject to different considerations from an overground transmission system, and it was found that to transmit the same energy, having regard for all of the conditions, there would be no advantage in the transmission system is a voltage higher than 15,000; in fact, the maximum advantage occurred at that point.

I make particular mention of this in that the installation has been designed to distribute 250,000 kw. over perhaps the widest area that is likely to be encountered in municipal supply. This being, therefore, practically the limit of this class of installation, it would appear there is a natural division between voltages for generation in what may be termed a municipal system and in what may be termed a long-distance transmission system, the limiting commercial voltage for a municipal system placed underground being approximately 15,000 volts, whereas in the long-distance transmission, if overhead, three or four times this becomes commercial. At this higher voltage, direct generation is out of the question. It would appear, therefore, the particular answer would be that in practically every case generators of large size can be wound to meet the requirements of economical transmission in the largest type of municipal plant, but that in the case of long-distance transmission, step-up transformers in the generating station become a necessity.

A. Henry Pikler: The chief object in winding a generator for high voltages is to use it directly in connection with the transmission line and to do away with the step-up transformer, if this in combination with the generator is found more expensive than the high-voltage generator alone.

I assume that 22,000 volts was selected in connection with this paper, because it was thought that this is about the limit for which generators can be wound in the present state of the art. Since, however, there is a large range of transmission voltages still above 22,000—in such cases transformers must be used anyhow—I should more explicitly formulate the question like this: Is it practicable to operate transmission lines from 20,000 to 25,000 volts directly by generators wound for such voltages?

What is meant by practicable? By this term I understand collectively the following elements in question: 1. Whether or not the apparatus can be built at all for such a voltage. 2. Whether or not it is economical to the manufacturer to build it for such a voltage in preference to other solutions. 3. Whether or not such a generator is reliable in the service; that is, economical from the standpoint of the power-plant man.

The very fact that there is some discussion over the practi-

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cability of 22,000-volt generators, may readily convey the impression that winding generators, even large generators, for 22,000 volts, is a great feat. Generally speaking it is not. It is not the art of insulating that is at fault in this problem. It is not that materials cannot be found good enough or that we do not know how to do the insulating, in order to have the generators stand the voltage in service.

The author introducing this subject for discussion illustrates very well with his 150 kilovolt-ampere, 22,000-volt generator, operating for months night and day without a break, that this is not the case. Though it is true that the quality of insulating materials has undergone rapid progress during the last four or five years, yet I know of machines wound for 20,000 volts that were installed seven years ago. These machines are not very large. They are horizontal turbine-driven, 150-rev. per min., 15-cycle, 1000-kw. machines. They can operate at 30,000 volts for half an hour without injury and they are operating satisfactorily.

I know of another plant installed about a year ago with 4000-kilovolt-ampere turbine-driven generators wound for 40,000 volts, and they are working satisfactorily. To wind and insulate a generator for 20,000 volts is, then, not out of the question.

The most essential thing needed for winding a generator for high voltages is space, big slots where there is space for the slot insulation, for insulation between adjacent turns or layers, and space on the ends to prevent creeping or breakdown between the ends of coils.

Big slots, however, mean an uneven distribution of magnetic flux, strongly developed higher harmonics, an electromotive force wave-form deviating from the sine wave, a higher excitation. It would be very interesting to know the electromotive force wave-form of the 150 kilovolt-ampere 22,000-volt machine, of which other characteristic curves are shown to advantage in the paper.

This wave-form is a very important matter, the manufacturer should consider it just as much as he does the possibility of a satisfactory insulation or the cost of a machine. There is no doubt but that even a 2000 kilovolt-ampere 300-rev. per min., 20,000-volt machine can be produced at a lower cost than can a combination of a 2300-volt machine and three 700-kilovolt-ampere step-up transformers. Besides, it would greatly simplify the power plant and lessen the responsibilities of the station men. It is doubtful, however, whether such a generator would be as good in every other respect, especially in wave form, as the 2300-volt generator. Besides, selling a generator and transformer, too, means greater profit to the manufacturer.

As to the reliability. A generator if protected by lightning-arresters, choke-coils, or even static-interrupters against abnormal rises in voltage is, to my mind, a safer and simpler proposition than a combination of a generator and transformer;

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on the other hand, if a breakdown occurs—in one case the transformer breaks and in the other the generator—there is no doubt but that it will take more time to repair the generator than to cut out the injured transformer and run the other two on open delta, or to repair the transformer, or to cut in a spare transformer.

Which solution is the most economical to the customer is almost solely dependent upon local conditions. For instance, in steel works or ore-smelting works where large blast-furnaces are electrically operated and where in case of a breakdown costly furnaces and valuable ore are affected, it will pay to carry in reserve even a complete generating outfit.

As the practicability in winding alternators for high voltages depends chiefly upon their geometrical dimensions, I cannot accept such a general conclusion as arrived at by the author of the paper. If he had in mind a steam turbine, he is about right, but I am of the opinion that lower generating capacities can be wound and used to advantage for 22,000 volts.

Bertrand P. Rowe: From the standpoint of the man who has to provide for the switching devices, the proposal to wind alternating-current generators for higher voltages than are commonly used at present seems to be a step in the right direction. As the size of unit increases, and the amount of energy to be interrupted becomes greater, it becomes more and more of a problem to build oil-switches that will open the circuits from the bus-bars, because the lower voltages now employed introduce currents of large capacity.

The problem of breaking circuits at high voltage has been successfully solved as far as pressure is concerned. It is a simple matter to open a circuit for any generator voltage that is likely to be determined upon. But if this circuit must carry a large ampere capacity, the problem becomes more difficult; and the higher the generating voltage becomes the simpler will be the problem.

Oil circuit-breakers have been built to open circuits carrying 2000 amperes normally at 13,000 volts pressure, and there have been cases where engineers have asked for circuit-breakers to open 3000-ampere circuits at 13,000 volts pressure. Here we are getting to the point in oil-switch design where it is doubtful engineering at best to build the switch and be ready to guarantee its successful operation.

If it were only the generator capacity that must be taken into consideration, it would be some time before arriving at a point where the switch must break any extraordinary current with present generator voltages. But the fact is that the use of low voltages on the bus-bars means heavy capacities in the junction and tie-in switches, and on circuits feeding large capacity transformer banks. The latter must often be automatic, and when opening on heavy overloads in a station with enormous capacities on the bus-bars, the result may be imagined. As the entire

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operation of a plant may depend on the success or failure of such switches, connected as they are to the bus-bars, the importance of this phase of the situation is obvious.

The problems involved on account of higher generating voltages in the other switchboard apparatus and the wiring of the station are not worth mentioning. The only appreciable difference will be that the higher potential will have to be provided for in the cables between the machines and switchboards. It is really a installation problem that has already been solved.

Comparing the cost of switchboard apparatus and conductors, everything is in favor of the higher voltage. It may cost a little more for insulated cables, but the oil circuit-breakers, bus-bars, series transformers, and other accessories will be smaller in capacity and much cheaper. It often happens that switchboard apparatus for a 13,000-volt plant with a given ampere capacity can be used without change for a plant of the same capacity at 22,000 volts, for the reason that the manufacturers have one class of apparatus for both purposes.

Summing up the whole situation, the use of higher generator voltages will simplify the problem in the switchboard equipment, and undoubtedly reduce the cost, besides involving nothing that has not been well developed and in successful operation.

A. B. Reynders (by letter): High voltages are independent of the prime mover; that is, the insulation on a 22,000-volt generator would be practically the same whether driven by hydraulic turbine, gas engine, reciprocating steam engine, or steam turbine.

As stated by the author, increase of voltage means increase of conductors. Increase of conductors means increase of insulation; hence, the higher the voltage the greater percentage of slot space occupied by the insulation. This, from a mechanical point of view, is inefficient. In the case of the 11,000-volt generator, cited by the author, it is probable that 50% of the space in the slot was taken up by the insulation, the remaining 50% being copper. Increasing this voltage to 22,000 volts and the capacity to 15,000 kw. will cause the insulation to be doubled; or, in other words, the space occupied by the insulation will be 70% of the total slot space.

When it comes to the insulation on the ends, the distance which the bare parts of the coils will have to project will be about double that required for 11,000 volts. This means that the coils will be extremely weak mechanically, owing to their length. This assumption is based on the fact that peripheral speeds cannot be increased much over the present uses; hence the increased induction must be obtained by lengthening the iron.

The increase in insulation has another very bad feature besides occupying valuable space; namely, it is a non-conductor of heat. All heat generated in the copper must be transmitted to the surrounding cooling medium through the insulation. Under the action of heat all insulation of a fibrous nature tends to

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deteriorate. Mica and asbestos are exceptions, but these are grave objections to their use unless combined with some fibrous material, such as tape. This deterioration of insulation is reduced by decreasing the heat generated, to accomplish which necessitates an increase in the size of copper. This again tends to decrease the efficiency per pound of gross weight.

As admitted by the author, a 22,000-volt generator is less reliable than one of 11,000 volts. That this is a grave weakness is endorsed by his statements regarding spare parts. He recommends practically an extra machine to provide against breakdowns. The only advantage which can be claimed is in simplicity of the power station by avoiding use of transformers.

Guido Semenza (by letter): Mr. Behrend rightly points out that the reason for using high-tension generators is to limit their current capacity, as the distribution and conduction of large currents from the generators to the switchboards is cumbersome and expensive. I would add, that up to a certain point switching with high pressure is preferable to switching with very heavy current.

In his comparison the author refers very likely to central stations having such a switchboard scheme that the low-tension generator currents are collected on a set of bus-bars to which the low-tension circuits of the transformers are connected, and, as far as such scheme is considered, I quite agree with him in his conculsions. But there is an intermediate solution between this and the use of high-tension generators which is employed in some European plants. Low-tension generators are used, and each generator is connected to a set of transformers, with circuit-breakers; there are no switches, no fuses, nor instruments being used in this low-tension connection.

The generator and its transformers are considered as a high-tension generating unit, and all the switchboard is on the high-tension side of the transformers. Such a solution permits of all the advantages of low-tension generators, confines the high-tension in an apparatus much more fit to withstand it, and at the same time reduces the current capacity in the switchboards.

It has only one apparent drawback; that is, that a fault in a transformer will also put a generator out of service; but if the use of low-tension will have the effect of reducing the number of accidents in the generator, then there will still be an advantage, as the repairing of generator coils requires much more time than the time required to replace a faulty transformer with a spare one.

Philip Torchio (by letter): Referring to Mr. Behrend's question as to what part the ohmic resistance plays in the parallel operation of synchronous apparatus on long transmission lines, I wish to call the attention of the parties interested in this subject to a paper contributed by Mr. G. Semenza to the Milan section of the Associazione Elettrotecnica Italiana, at their meeting of December 4, 1903.

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The paper describes two series of tests: one upon two direct-current synchronous motor-generator sets, operated inverted from a large storage-battery and with the alternating-current machines connected through an adjustable resistance. The other series of tests was made on a synchronous motor fed from the main bus-bars of a large generating station through an adjustable rheostat. In both cases the load and power-factor and reactance and ohmic resistance of circuits were adjusted for different values so as to obtain curves showing the behavior of these machines. Pumping phenomena would appear in all instances under certain conditions of load, power-factor, and ohmic resistance of the circuit. The pumping had a frequency of from eighty to one hundred and twenty vibrations per minute, and beyond certain values the amplitude of the oscillation was so large that the machines were thrown out of step.

Mr. Semenza's analysis of the results gives lucid portrayals of the function of resistance and reactance in a circuit upon the parallel operation of synchronous motors, and possibly might be abstracted for the minutes of the Institute, or at least attention called to this contribution to the subject for the information of those who may care to look up the subject.

John Pearson (by letter): I agree that there are advantages in winding large alternators for 22,000 volts, especially when this is the potential required for distribution. As Mr. Behrend says, steam turbines will probably soon be built for 10,000 to 25,000 kilowatts. These large steam units will naturally be used in large cities where the distance of transmission is relatively short. Hydraulic turbines in the near future will possibly range in capacity, as at present, from 1,000 to 3,500 kilowatts. These turbines will, on the average, be used at a distance from the market or center of distribution, where the distance of transmission will be relatively long.

I believe it practicable to wind 22,000-volt alternators for use with large steam turbines where the distance of transmission is short. In this case, power stations using 22,000-volt alternators will need no step-up transformers, resulting, of course, in higher efficiency. The danger of generator coils being punctured directly by lightning will be small, as the average turbo-generator will be transmitting its power through underground cables.

The transmitting voltage of the future water-power station is likely to be from 60,000 to 100,000 volts, and one would not favor using, a 20,000-volt alternator where the transmitting potential was 60,000 or 100,000 volts, as transformers for raising the potential would also have to be used. Where step-up transformers have to be used, I believe it practicable to use generators wound for 2,200 volts, as there is very little danger of the generator coils giving way at this voltage.

A generator wound for 22,000 volts can, as far as insulation is concerned, be compared to an air-blast transformer. I know

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by experience that the oil-insulated transformer will stand more severe static strains than the air-blast transformer. Consequently, a 20,000-volt generator cannot be expected to stand up under severe static strains any better than can the air-blast transformer, on account of not having the benefit of oil for insulation. Oil simply for insulation is not all, as the oil fills all intermediate space between and around the coils and thereby keeps the dirt away from the coils, which is one good point.

Mr. Behrend states that the insulation of coils against ground is easier to obtain than against one another, and that the question of insulating the coils from one another is particularly difficult in turbo-generators on account of the crammed conditions of the winding space. From the above it is seen that no more insulation can be used than what is absolutely necessary; but it is comparatively easy to bring out leads and use cylinders and air-gaps, as shown in TRANSACTIONS A. I. E. E., 1904, Vol. 23, p. 570. Also TRANSACTIONS A. I. E. E., 1905, Vol. 24, pages 960-962-978.

I know by experience that when using spark-gaps across each coil, less insulation can be used, as abnormal strains are equalized over the whole winding. I do not consider it hard to insulate a generator for 22,000 volts under normal conditions, but such generators must stand up under abnormal static conditions as well.

It seems wise, therefore, to use spark-gaps across coils, the winding connected in star and the star and core grounded. By this arrangement the generator becomes to a certain extent a condenser, having capacity between coils; between coils and the frame, between coils and the ground, this capacity becomes more noticeable when any static strain can reach all parts of the winding at once, than if it only piled up on the first coil nearest the transmission line.

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(Subject to final revision for the Transactions.)

AN ANALYSIS OF THE DISTRIBUTION LOSSES IN A LARGE CENTRAL STATION SYSTEM

BY L. L. ELDEN

The central station system under consideration is typical of those in service throughout the country, serving the larger centers of population and including adjacent suburban districts within a radius of upwards of fifty miles from the main generating station.

This system, as is the case with many similar systems, comprises the business of a number of companies that have been amalgamated into one large organization. This larger organization, with its greater financial resources and highly trained administrative and engineering forces, has naturally proved better fitted to meet the demands for service arising from an area of 450 square miles, in which thirty cities and towns, having a population of 1,000,000 persons, are served by the system.

Of the 1800 miles of streets included in the territory, 750 miles are covered by the lines of the system, which extend 43 miles in a single direction from the generating station. The total 50-watt equivalents connected to the system aggregate 1,600,000, equal to 80,000 kilowatts. This load comprises the usual mixture of power, heating, and lighting apparatus which constitute the business of a central station system. The maximum demand is approximately 44% of the connected load at the time of the yearly maximum, and approximately 27% during the average days of the year. These two results are indicated by Fig. 1, which shows the average load curves of the system for the maximum and average days of the year 1906.

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The generating equipment consists of two main generating stations, one generating three-phase, 60-cycle alternating current exclusively, and the other generating low-tension direct current. In addition there are two small generating plants located at remote parts of the system, which are still in service independent of the main system. When convenient, these will be discontinued as generating stations and converted into sub-stations supplied with current from the main generating station. To facilitate the distribution of current over the large territory, sub-stations are maintained at suitable centres, at which points the high-pressure transmission lines deliver 60-cycle, three-phase, alternating current for conversion to direct current and alternating current at voltages suitable for commercial purposes.

As will appear in some of the tables given later, three transmission pressures are used; namely, 2300 volts, 4600 volts, and 6600 volts. In explanation of the apparent complication of voltages in the transmission system—it was found more convenient and economical to maintain certain installations of underground cables and motor-generators which were acquired in the purchase of another company's plant, than to abandon the large investment represented by such equipment. All new installations are made at 6600 volts, it being the intention gradually to eliminate the lower transmission voltages as conditions may dictate.

Throughout the entire system but three forms of service are supplied for commercial purposes; that is, either low-tension direct current, single- or three-phase alternating current.

The low-tension, direct-current district, representing slightly less than 1% of the total area of the system, is supplied exclusively by three-wire direct-current at 115–230 volts. This is used indiscriminately for power, lighting, and heating service.

Similarly, the alternating-current district, embracing 99% of the area, is supplied exclusively by the alternating-current system of distribution. Three types of primary distributing circuits are used in the various sub-station districts, according to the demands for service, as follows:

1. 2300-volt, single-phase circuits in resident districts where only lighting and small power service is required.

2. 2300-volt, three-wire, three-phase circuits are used in districts of limited areas where mixed lighting and power service of considerable amounts are to be furnished.

3. 2300-volt, four-wire, three-phase circuits are used in

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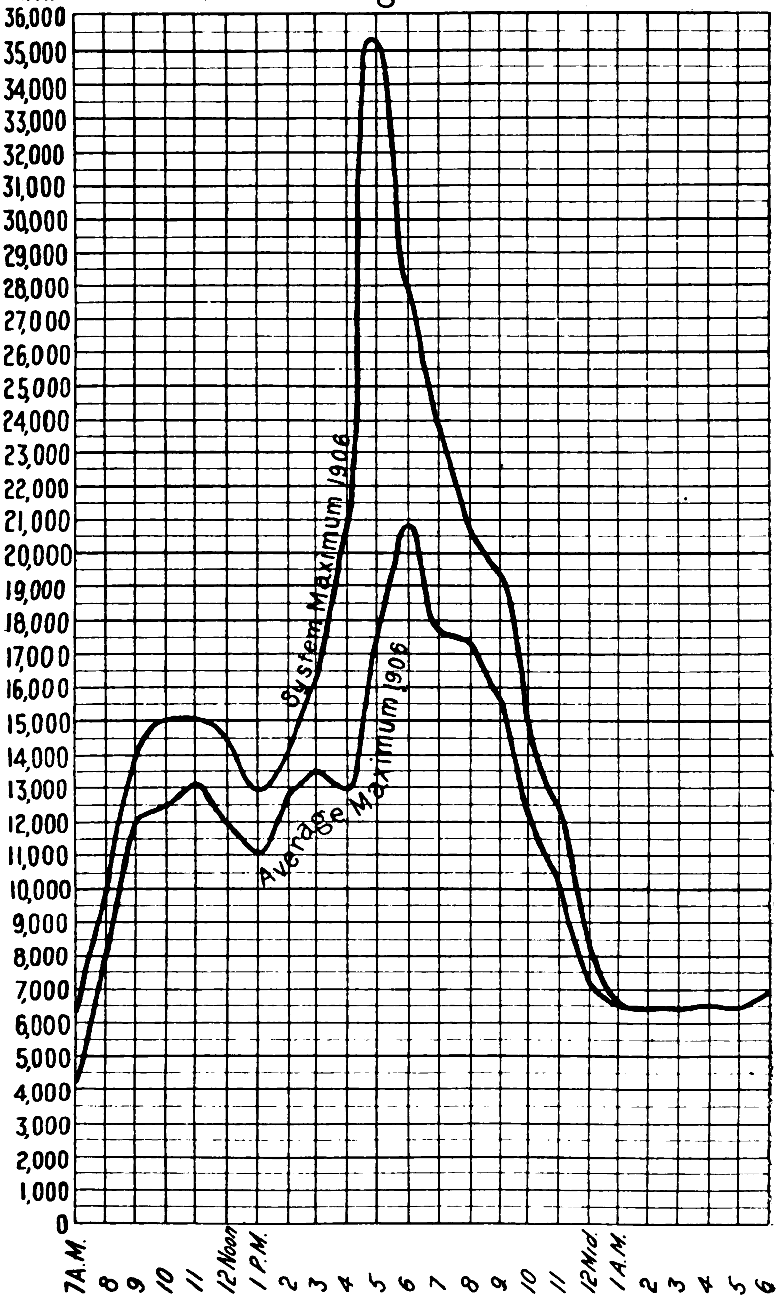
Fig. 1



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districts covering large areas where mixed lighting and power service is furnished.

In each of these cases, however, service is furnished to the customers at 115–230 volts, single phase, for lighting and small power service, and 230 and 550 volts, three phase, for power service.

In addition to the types of service previously referred to for commercial service, there remains the street-lighting service, which is supplied at 6.6 amperes direct current, or alternating current, for both series-arc and incandescent lamps. In one district 3.5 amperes series incandescent lamps are used, but this is not considered as standard, and is subject to change when convenient.

To place the system on the basis described above has not been so simple a procedure as may seem from a cursory reading of the preceding statements. With the acquisition of each new interest and its territory, it was found that special forms of service were being supplied to customers, in most cases differing from those which are now considered as standard. As a result, at one time in 1903 some twenty different forms of service were being supplied to customers, with the attending complications in operating. Special apparatus was maintained and operated to supply these different services, with results far from economical; and, while much of the apparatus in service was as modern as it was possible to be, some could scarcely be considered in that class.

It was apparent from a comparison of the kilowatt-hours sold, with the kilowatt-hours generated, that the difference was too great to be consistent with good practice. To ascertain the reason a complete survey of the whole system was undertaken with a view of eliminating the uneconomical features. This investigation involved an examination of each customer's connected load and demand; the capacity of and demand on each transformer in the alternating-current district; the losses in transmission lines, feeders, and mains; the operation of all station apparatus; the accuracy of all recording meters—in short, all the details of the uses of current by the company and its customers. As a result of this inquiry, it was deemed advisable to proceed with the necessary changes. These changes which were commenced in 1903 affected the following parts of the system.

A certain district was specified in which no form of service other than the three-wire, 115–230-volt, direct-current service

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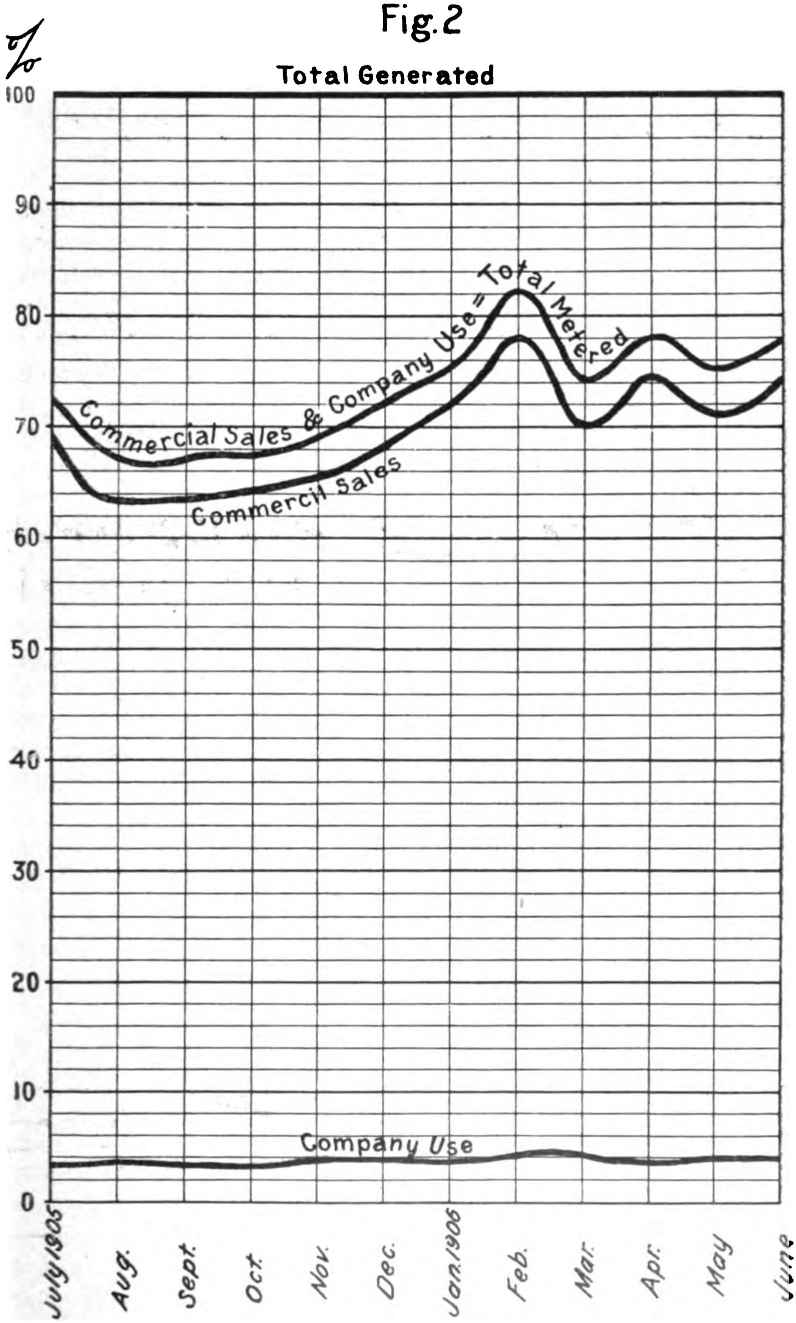
Fig. 2



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would be supplied. This made it necessary to transfer all the alternating-current customers affected, to the direct-current system, remove all transformers in this district, and re-connect the alternating-current mains as a part of the direct-current system.

The 500-volt direct-current service was abandoned, and all motors located in the direct-current district were adapted for 230-volt, direct-current operation, while such as were outside of the direct-current district were replaced by alternating-current motors.

A number of new sub-stations were installed in the direct current districts to provide for serving the rapidly increasing business of the company, and, at the same time, to reduce the excessive losses in feeders and mains by shortening and rearranging the distributing points of existing feeders, as well as the addition of new ones.

In the alternating-current district secondary networks were installed and the number and capacity of transformers reduced, the total reduction in this case being 30% of the installed capacity. Changes in sub-station apparatus were effected by the introduction of new apparatus, all adapted to supply the standard forms of service.

The results of these changes may be seen by reference to

TABLE II.

	Kilowatt-hours generated.	Kilowatt-hours sold.	Percentage of kilowatt-hours sold
Year ending June 30, 1903........	49,122,344	31,569,741	64.26
" " " " 1904........	57,531,315	37,220,199	64.67
" " " " 1905...... ..	64,161,987	41,910,281	65.31
" " " " 1906...	74,582,311	52,003,000	69.82

To illustrate further the increased efficiency, Figs. 2 and 3 are presented, covering the operation of the system for 12 months ending June 30, 1906. Fig. 2 shows the percentage of sales and company's use for the year by months, and Fig. 3, the actual sales and company's use in kilowatt-hours for the same periods.

In Table II, it will be seen that there was an increase in four years of 5.56% in the sales as compared with the manufactured kilowatt-hours. This result, however, is an average for the whole year 1906. Referring to Fig. 2, it will be seen that for the last six months of the year the average is much

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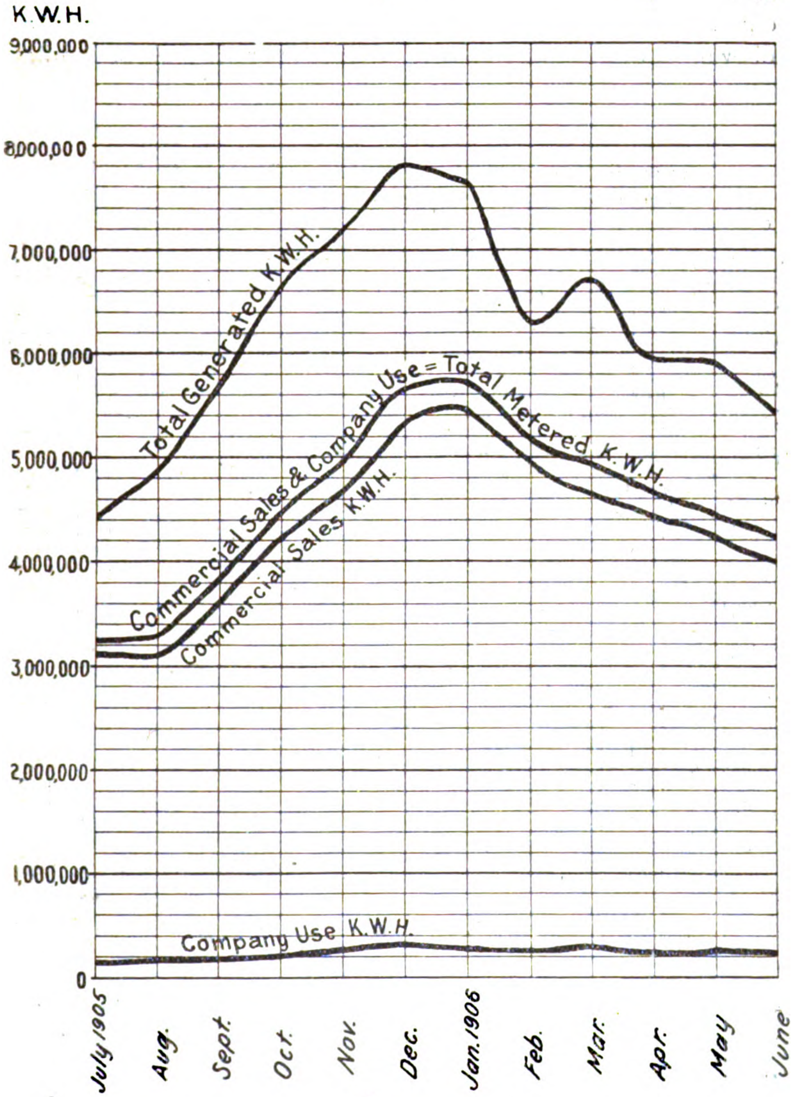
Fig. 3



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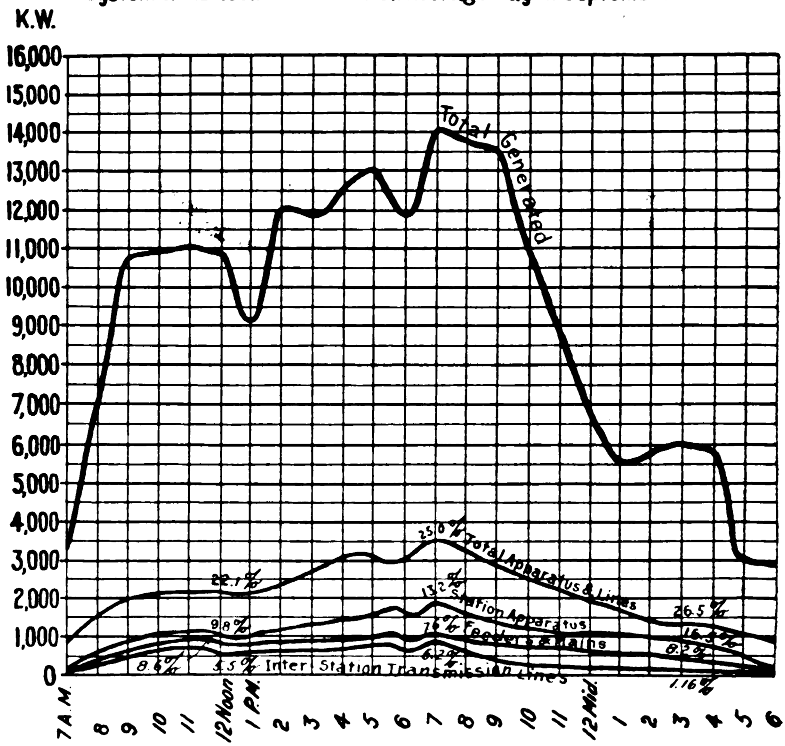
higher, it being actually 73.65%, this figure indicating future possible results.

It will be noted that the curves in Figs. 2 and 3 show an abnormal percentage of sales for the month of February; this is explained by the fact that the station data on manufactured kilowatt-hours for February represent a month of 28 days, while

Fig. 4

Curves of Instantaneous Losses in the Electrical Equipment of the System at 12 Noon 7 P.M. 3 A.M. on average day in September 1905



the total sales represent an average month of 30 days. Other points in these curves which do not coincide may be attributed to the same cause.

Using the data for 1906 as given in Table II as a basis, it will be seen that it would have been necessary to manufacture approximately 5,000,000 kilowatt-hours more in that year to sell the same amount of current, if the conditions had been

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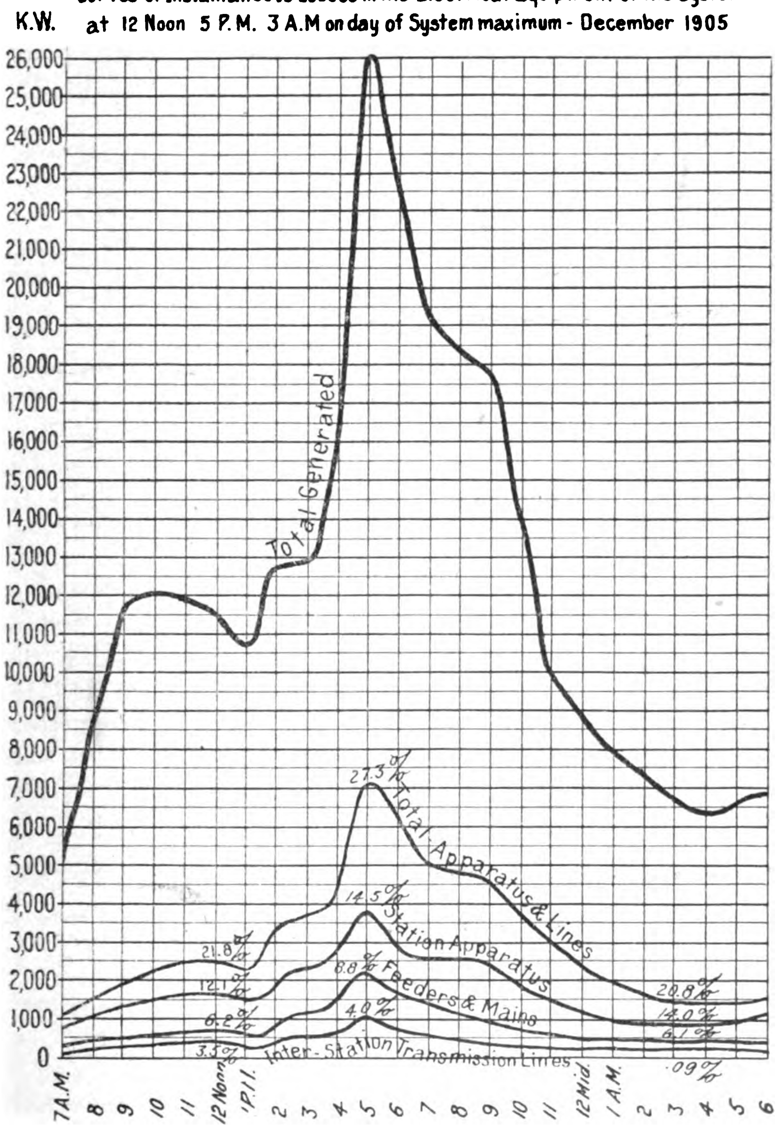
Fig. 5

Curves of Instantaneous Losses in the Electrical Equipment of the System at 12 Noon 5 P.M. 3 A.M on day of System maximum - December 1905



the same as existed in 1903. Further, if the average of the last six months of 1906 had been maintained throughout the year, a further saving of 5,000,000 kilowatt-hours would have been made during the year. While the resulting economies have in themselves justified the time and outlay necessary to make the changes, the increased capacity of the system, as well as the simplifying of the operating conditions, have been results far outweighing all other considerations.

In Figs. 4 and 5 are shown curves representing the maximum generated kilowatts, also the instantaneous losses which occur in the system at different hours on the average and maximum days of the year. These data, while of no particular value, may be of interest in comparison with the continuous duty losses shown in some of the succeeding tables.

As it is the practice of this company to use motor-generators in preference to synchronous converters, to transform the three-phase current to direct current for the supply of service to the 115-230 volt, three-wire, direct-current system, it may be suggested that a further economy could have been effected by the use of converters.

The motor-generator equipment of the company comprises 36 units having a total capacity of 10,210 kw., and varying in size from the 1,000-kw. direct-connected sets, to the 60-kw. Edison bipolar belted units which have been retained in service in some of the smaller stations. In Table 3 are shown the actual results of the operation of this apparatus for the year 1906. There is also shown the estimated results of the use of converters of the same sizes, operated in the same manner as the motor-generators, and at an assumed efficiency calculated from the manufacturer's data on such sizes of apparatus.

TABLE III.

	Kilowatt-hours received.	Kilowatt-hours delivered.	Per cent. efficiency.
230-volt motor-generator..........	31.331.406	25.803.990	82.4 actual
230-volt converters...............	30.004.639	25.803.990	86. assumed
Kilowatt-hours saved by use of converters.......................	1.326.767		

The operating efficiency of the converters is estimated at 87%, less 1% for the current used by the cooling apparatus, while the efficiency of the motor-generators was 82.4%. The table

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shows a saving of 1,326,767 kilowatt-hours by the use of converters, this representing the premium paid for the use of the more reliable apparatus, in addition to which there is to be added the slightly larger investment necessary in the purchase of motor-generators. Owing to the well-known difficulties incident to the operation of 60-cycle converters in a large system where continuous service is placed above all other considerations, it is a question of individual opinion whether a company is justified in adopting either type of apparatus.

TABLE IV

Comparative data of alternating-current and direct-current systems

	Alternating current	Direct current
Area of system per cent. of total	99.1%	0.9%
Connected load per cent. of total	21. %	79. %
Commercial service, street lighting service omitted		
Total losses from generating stations to customers' meters	41. %	20. %
Efficiency of system	59. %	80. %
Total losses from sub-stations to customers' meters in percentage of current delivered from sub-station	24. %	7.5%
Efficiency of distributing system	76. %	92.5%
Street lighting system		
Total losses from generating stations to street lamps	15.2%	31.9%
Efficiency of system	84.8%	68.1%
General data		
Connected load in kilowatts	17300	62700
Capacity of transformers installed on distributing circuits	10388	——
Capacity of transformers in per cent. of connected load	60%	——
Approximate kilowatt-hours delivered to each system in per cent. of total generated	30%	70%

Table 4 presents some data illustrating the comparative losses in the alternating-current and direct-current systems as operated. In the alternating-current system the total losses, including transmission, step-down transformer, distributing circuit losses, and meter losses, aggregate 41.1%, equivalent to an efficiency of 58.9. Eliminating the losses in transmission lines, step-down transformers, regulators, boosters, etc., the total losses in the distributing circuits, meters, etc., aggregate

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24.2% with a resulting efficiency of 75.8% from the sub-station to the customers' meters.

In the direct-current system the total losses, including those in transmission lines, motor-generators, tie-lines, feeders and mains, meters, etc., aggregate 20%, equivalent to a system efficiency of 80%. Eliminating all losses in the direct-current system, except those which occur between the direct-current switchboard in the sub-stations and the customers' meters, a total loss of 7.54% is shown, or an efficiency of 92.46%.

Two forms of street-lighting service are in use, each involving the operation of different types of apparatus. In one case motor-generators are used to convert alternating current to 6.6-ampere series direct current, and in the other case constant-current-transformers are used to obtain the 6.6-ampere series alternating current for similar service.

TABLE V.

DISTRIBUTION OF CURRENT FOR THE YEAR ENDING JUNE 30, 1906

	Kilowatt-hours.	Loss in per cent. of total generated kilo-watt-hours	Per cent of generated Kilowatt-hours transmitted
Commercial sales	52,003,000	69.82	
Company use	2,774,383	3.72	
Total losses	19,270,616	25.87	
Unaccounted for current	441,437	0.59	
Total generated	74,489,436	100.	
Sub-division of Total Losses			
Losses in station apparatus	10,586,117	14.21	16.6
Losses in inter-station transmission lines	2,920,653	3.92	5.92
Losses in feeders and mains	5,763,846	7.74	10.50
Total losses station apparatus and lines	19,270,616	25.87	

The total losses in the 6.6-ampere direct-current system are shown to be 31.9%, giving an efficiency of 68.1%. For similar service from the alternating-current system, the total losses are 15.2% with a resulting operating efficiency of 84.8%.

The methods employed in preparing the data by means of which the losses in the system are determined may be understood by reference to Tables 5, 6, 7, 8, and 9. These tables

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present a summary of the year's operation. Similar tables are prepared monthly which deal with the shorter period of time.

It should be understood that with the exception of such items in these tables as are preceded by an asterisk, all the data shown are the results of records taken from recording wattmeters. In such items as are excepted, computations were necessary, all of which were made from reliable data furnished by the manufacturer of the apparatus in question, supplemented in many cases by tests made by the company's representatives.

The losses in the individual commercial distributing circuits were determined by the drop-of-potential method, a constant being obtained for each circuit by taking a large number of

TABLE VI

LOSSES IN STATION APPARATUS FOR THE YEAR ENDING JUNE 30, 1906

	Kilowatt-hours	Loss in per cent. of total power generated	Loss in per cent. of input
230-volt motor-generators	5,527,416	7.42	17.6
560-volt motor-generators	373,059	0.50	33.6
Series arc motor-generators	2,403,471	3.22	25.5
Step-down transformers	1,010,848	1.36	3.23
*Constant-current transformers	118,548	0.16	5.40
*Potential regulators	65,353	0.09	3.53
Batteries	807,067	1.09	43.2
Boosters	211,264	0.28	63.0
Balancers	67,725	0.09	
Water rheostats for testing	1,366		
Total	10,586,117	14.21	

pressure tests under all conditions of load. The losses in the direct-current mains were estimated in the same manner. The losses in the street-lighting circuits were calculated from the known length of the circuits, and these results further checked by voltage readings at the station while the circuits were in operation with a known number of lamps burning.

Every year the company makes thousands of tests of the meters in use on the customers' premises. For the year 1906 the results of all such tests showed that the average meter error was 2.6% slow. This factor has been used to account in part for some of the unknown losses, the total thus accounted for being approximately 1.5% of the total power generated.

Table 5 shows, in the first part, a summary of the principal

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TABLE VII

LOSSES IN INTER-STATION TRANSMISSION LINES FOR THE YEAR ENDING JUNE 30, 1906

	Kilowatt-hours	Loss in per cent. of total power generated	Loss in per cent. of input	Per cent. of total generated power transmitted
Three-phase 2,300-volt lines	1,556,981	2.09	8.41	24.8
Three-phase 4,600-volt lines	98,813	0.132	1.52	8.7
Three-phase 6,600-volt lines	770,577	1.04	3.55	29.1
230-volt direct-current tie-lines	494,282	0.66	18.30	3.6
Total	2,920,653	3.92	5.92	

TABLE VIII

LOSSES IN FEEDERS AND MAINS FOR YEAR ENDING JUNE 30, 1906

	Kilowatt-hours	Loss in per cent. of total power generated	Loss in per cent. of input
*2,300-volt commercial lines	1,854,854	2.50	25.1
230-volt direct-current feeders	1,901,948	2.55	4.93
*230-volt direct-current mains	641,343	.86	2.00
*500-volt direct-current feeders	74,466	0.10	9.15
*Street-lighting circuits	809,103	1.08	9.53
*Meter potential losses	482,132	0.65	
Total	5,763,846	7.74	10.5

TABLE IX

DIVISION OF KILOWATT-HOURS SOLD BY DISTRICTS FOR THE YEAR ENDING JUNE 30, 1906

Station	Per cent. kilowatt-hours received	
1-13	68.9	
14	100.	
15	100.	
16	75.	
17	98.3	
18	63.5	
19	55.4	
20	52.4	
23	55.9	
25	72.8	
	69.8	Total System Sales

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items without subdivision. The latter part of the table subdivides the total losses in the system into divisions which are treated individually in the later tables.

In Table 6 the losses in station apparatus are subdivided and distributed among the various pieces of apparatus used in the operation of the stations.

Table 7 indicates the losses in the inter-station transmission lines.

Table 8 shows similar data on feeders and mains.

Table 9 shows the percentage of sales in each sub-station district as compared with the current delivered to that district for distribution. In explanation of this table, it should be noted that stations 1 to 13 include the direct-current district and a portion of the alternating-current district. Stations 14, 15, and 17 represent stations to which current is sold wholesale, to be redistributed by the local companies controlling these districts. Stations 16, 19, 20, and 23 represent sub-stations, each of which distributes service to one or more cities or towns in the suburban districts. Stations 18 and 25 represent small generating stations which are still in service in two of the recently acquired suburban districts.

In making comparisons of the several districts, some of the individual characteristics of each district should be understood. Station 16 supplies a district where large amounts of power are used, also a large amount of street-lighting service. Station 18 supplies a district similar to 16, except that the amounts of power and street lighting service are relatively less.

Stations 19, 20, 23, and 25 supply service to districts covering large areas where resident lighting and a moderate amount of street lighting are the only uses made of the service.

The preparation of these data involves the labor of one man for a period of approximately one week each month. It is his duty to watch the operation of the system through the statistics furnished him by the operating and sales departments, comparing them with data which have been prepared representing the possible maximum conditions of efficiency of operation of every piece of apparatus and reporting for investigation any divergence from the estimated average operating losses. The curves, which are prepared monthly, show the percentage of losses in the current handled by each motor-generator, storage-battery, balancer, booster, exciter, step-down transformer, constant-current transformers, or any other station apparatus,

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thereby providing means for immediately detecting any unusual results, and furnishing an invaluable check on the operation.

Aside from the value which these data may have from an operating point of view, it is of considerable interest in indicating the characteristics of each district as a revenue producer, thus making it possible to judge accurately of the advisability of making extensions for the different classes of service.

If there should be undertaken at this time the construction of a generating and distributing system similar to the one under consideration, the installation would be made under conditions which would eliminate the disadvantages encountered in reconstructing existing equipments, as in the present case. This would be particularly true in certain parts of the country, where the limitations placed by the local authorities on permissible operating conditions are less severe, and where the quality and the continuity of the service are not of such paramount importance,—all such conditions tending to greater economy and reduction of operating losses than is possible in the present system.

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DISCUSSION ON "RELATIVE MERITS OF THREE-PHASE AND ONE-PHASE TRANSFORMERS," AT CHICAGO, ILL., MAY 24, 1907.

(Subject to final revision for the Transactions.)

Peter Junkersfeld (by letter): A decision as to the use of three one-phase transformers or one three-phase transformer should take into consideration all local conditions. The five disadvantages enumerated by Mr. Peck will in some cases be so great as to prohibit the use of three-phase transformers; in other cases these disadvantages may be negligible.

In a small system, or in any system in which the total number of units are few, the "greater cost of spare units" and "greater derangement of service" often throws the balance in favor of three one-phase transformers. However, the troubles with, or breakdowns of, three-phase transformers have perhaps been less than is generally supposed.

The Chicago Edison Company had in service on May 1, 1907, about 42,000 kw. of three-phase transformers, which type it has installed exclusively in connection with synchronous converters during the past six years. The one-phase transformers installed previously for converters aggregate about 8,000 kw. The company also has in service as step-up and step-down transformers for generators or lines a total capacity of about 6000 kw.

In reviewing the ten years' experience in which the one-phase transformer capacity has grown to 14,000 kw., and the six years' experience in which the three-phase transformer capacity has increased to thirty-two units varying in size from 550 to 2200 kw. and aggregating 42,000 kw., we have found that the total number of "troubles" where transformers have been taken out of service have been less with the three-phase than with the one-phase transformers. In fact, there was only one case worthy of notice with three-phase transformers, and even in this the damage was not serious. The one-phase transformers varied in size from 100 to 500 kw., some oil-cooled and some air-blast.

A fruitful source of transformer troubles are the taps for various voltages and the wiring inside the top of the transformer. The above mentioned three-phase transformers were not adopted until the system was so well developed that a great multiplicity of taps was no longer necessary. This, with the particular attention paid to the wiring inside the top of transformer, accounts partly for the few troubles with the three-phase transformers. The latter also embody all of the latest developments in transformer design known, having been in service little more than six years, while some of the one-phase transformers have been in service for a much longer period and are thus of earlier design.

In small and often uncertain undertakings, and in pioneering or extraordinary extension work, there are cases where three-phase transformers should not be used. The advantages

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of three-phase transformers are, however, so great and the results obtained are so good, both in this country and in Europe, that the use of three-phase transformers merits the most careful consideration in every case. The undertaking that is small to-day may become large to-morrow, and the growth or change in condition usually makes the situation more favorable for the three-phase transformers.

R. F. Schuchardt: Our experience has been of such a nature as fully to justify the decision made six years ago to adopt the three-phase transformers in our converter sub-stations. Where the installation is connected to an overhead line, or where the units are small in number, the situation is, of course. different. I refer to an installation such as ours where the system is very large and has underground transmission lines throughout. The disadvantages enumerated by Mr. Peck almost entirely disappear in such a system. Taking them individually:

"Greater cost of spare unit". An individual unit being only a very small portion of the total installation, the expense is comparatively small and the saving due to use of three-phase transformers will more than offset this.

"Greater derangement of service in the event of breakdown" and "Greater cost of repair". The transformer breaks down so seldom that one can very well afford to take the risk, especially in view of the advantages.

"Reduced capacity obtainable in self-cooling three-phase units". Units of this kind are not generally used self-cooling. A blower system is usually installed in order to get greater capacity out of the apparatus.

"Greater difficulties in bringing out taps for a large number of voltages". As Mr. Junkersfeld has said, the transformers are now so well standardized that a large number of taps are not required. We do not even avail ourselves of the advantage to be obtained, in case of part breakdown, by having the delta connection on both primary and secondary. We connect the secondaries in star and then join the star points together and to the neutral of the three wire direct-current system. The converters thus also serve as balancers.

C. W. Stone: Most of the discussion seems to be based upon the larger size units. I think that we ought to consider the small unit for pole work. I think this is one of the places where three-phase transformers are particularly well adapted. On poles we are always crowded for space, and that is where we need the smallest unit that we can get for the maximum output. That means the three-phase transformer.

Another point, which has not been mentioned at all, is the underground circuit in manholes. I do not think there is any place more crowded or any place that gives more trouble than the apparatus installed in the manhole. Therefore the three-phase transformer is particularly good in that place because the connections are so much simpler, and the trouble in the man-

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holes comes principally from a poorly made connection. In a three-phase transformer there are fewer of them and therefore less chance of poor work.

In large size units in large stations the question is not so much the question of cost of spare unit as it is the question of the design of the station. Frequently transformers are left until the last thing. The transformers and the switchboards are always left until after the station is designed, and then we have to tuck them away in some corner. Therefore the question is reliability. The extra cost of spare apparatus, etc., does not come into the question at all. It is a question how much we can get in the smallest possible space. There again we have the three-phase unit. As far as reliability is concerned and the cost of repairs, I think Mr. Schuchardt and Mr. Junkersfeld pointed that out very well. The total percentage of breakdowns and the total necessity for repairing is so small that I do not think it ought to come into the question at all. The three-phase transformers do not burn out any more than the single phase. In fact, the burn-outs are so few that we can disregard them entirely.

There was a question in Mr. Peck's paper about operating the three-phase transformer with a Y connected secondary, stating that with the delta connection we could operate with one phase cut out and operate the other two on open delta. This is also being done in many places with the Y connection using the ground return where the system is grounded. This has happened in a number of cases where three-phase units are installed and one of the lines has broken down and with a grounded neutral all the rotary apparatus and similar apparatus has gone on operating, and the sub-station man hasn't known that the main line was out until it was reported from outside.

Walter S. Moody: It is pleasant to find Mr. Peck such a thorough convert to the advantages of the three-phase transformer. It is to be regretted, however, that America had to lose so able an engineer before European practice convinced him of the wide range of usefulness of the three-phase transformer.

It was quite natural that American practice with its strong appreciation of the desirability of simplification and standardization of design and construction should for a long time have neglected the saving in cost, simplicity, etc., resulting from the use of three-phase transformers by using single-phase transformers exclusively. As the volume of transformers manufactured increased, however, the force of these considerations largely disappeared, due to the fact that larger transformer makers had such a large output that the cost of manufacturing a given capacity of both single- and three-phase transformers would not be appreciably greater than making the same capacity of single-phase transformers only. One not acquainted with the facts might conclude from remarks in Mr. Peck's paper that three-phase transformers have been in use in this country but a very

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short time and had been produced in very small quantities. While undoubtedly American desire for simplicity and interchangeability retarded more than it should the use of the three-phase transformers, I have strongly advocated their use for six or seven years, and have been responsible for the design and building of some 450,000 kw. ranging in size from five to 7500 kw. units.

Mr. Peck's paper puts the advantages and disadvantages most clearly, in my opinion, and in all important respects, most accurately. There are one or two minor points in connection with the relative advantages of the core or shell-type construction as applied to three-phase transformers on which I would differ slightly. First, with reference to the ease with which repairs may be made on the core type. I think the European practice of a removable yoke is sufficiently objectionable to offset its advantages. Bolts in a transformer core are always a source of danger, in that the insulation around them may become charred or otherwise damaged, thereby greatly increasing the eddy-current losses. The butt-joint between the yoke and the rest of the core can only be satisfactorily made if the surfaces that are to come in contact are milled or otherwise finished to a true surface. If the surfaces are not finished, or even if they are, the eddy current between the sheets in the two parts of the core may readily be sufficient to cause the welding together of the laminations that Mr. Peck mentions. Some manufacturers use thin sheets of paper between the two parts of the core to avoid this, but the thinnest paper results in a material increase in magnetizing current.

The labor involved in removing the yoke, if it be interleaved with the rest of the structure, is not so great as might be supposed. I have seen such a yoke on a 500-kw. transformer removed and returned to position in fifty minutes. This is certainly not a long time compared with the other necessary operations, including the removal of the transformer from the tank and the exchange of coils.

As one of the disadvantages of the three-phase transformer, Mr. Peck mentions the likelihood of a burn-out in one phase being communicated to adjoining phases. This is quite likely to happen in case of a bad short-circuit in the core-type construction, but I have never known it to happen in the shell type, as the large body of iron between the phases protects the copper in different phases, except the portion that projects beyond the cores, and at these points it is easy to put in a fire-proof barrier. Consequently, the somewhat greater ease with which the core type may be repaired is largely offset by the fact that the damage is likely to be less restricted in its extent than in the shell type.

I agree with Mr. Peck regarding those crosses between a single-phase and a three-phase transformer which consist of two single-phase transformers in one case connected open delta or T.

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While the **T**-connected sets have a limited field of usefulness, because they only admit of returning current to the neutral of the system, yet they are neither single nor three-phase, and like most compromises, are undesirable in many ways.

W. B. Jackson: One point has not been brought out which is certainly an important reason for our not having adopted the three-phase transformer in America. It has not been many years since the operator or the person in charge of an electric transmission plant, in a district where serious and destructive lightning troubles were encountered, held his breath during every lightning storm and he usually has had experiences where one single-phase transformer has gone out of business and the two remaining have saved the day without disturbing his service.

There is a statement in Mr. Peck's paper to the effect that for important work single three-phase transformers are used in Europe. I question whether, for what we would consider important power work, we should be willing, even with the present design of transformers, to use a transformer without some reserve. With the present improved transformer design, we have arrived at a time when the question of reserve is not so important as it was a few years ago, and when it may be policy in some cases to use a single transformer without reserve in cases where the service is not very important. But if we assume a condition where the light and power for a town, a small town if you please, is being supplied from the transformer the service demands a reserve. The same is true of a mining camp, especially so if hoists and mills are being supplied with power, and so it goes with most classes of service. One must have an arrangement by which a portion of the apparatus may be taken out of service and still the service will go on.

We all appreciate the tendency that the prevailing opinion has to change one's ideas on subjects, and I wonder how much the opinion of a person who changes his abode from America to the Continent will change. I remember, five years ago, discussing with a prominent engineer of Austria the relative advantages of using three-phase transformers for transmission work as compared with single-phase transformers. He was unwilling to be convinced that there was a single reason for the use of single-phase as against three-phase transformers until I took up the matter of the lightning conditions as they exist in America. He was then willing to admit that there might be cases where single-phase transformers would work into a power transmission scheme with advantage The feeling of this engineer seemed fairly to represent the opinions of most European engineers.

P. M. Lincoln: There is one objection to the three-phase transformer that has not yet been brought out. I refer to the matter of leads. In very high voltage transformers, say 60,000 volts and above, it is one of the most difficult elements of the design to bring out the leads properly, and where it is a question of bringing out three leads for 60,000 volts instead of one, as is

the case with a grounded neutral **Y** transformer, or two, as is the case with a single-phase transformer to work in delta, I believe the difference is quite considerable, and that the difficulty of bringing out those three leads in the case of the three-phase transformer as against the one or two leads in the case of the single-phase transformer is a question to be taken carefully into consideration. That objection applies only to the very high voltages. Even with two leads brought out, practically all the available space is taken up by those two leads.

If we have three transformers connected in delta it is possible, as we all know, to go ahead and do business on the two remaining in. However, when that occurs, either there must be an interruption to the service in order to cut out the damaged transformer (if it be damaged) or else we must have automatic apparatus such as reverse-current relays or something of that kind to cut out the damaged piece of apparatus automatically. Now reverse-current relays theoretically can be so constructed as to do that all right, cut out that damaged piece of apparatus and let the other two go on and do business. However, the experience that I have had with reverse-current relays and such apparatus would lead me to be rather doubtful whether in actual practice such a scheme will work satisfactorily. When we get a short-circuit on these high-tension lines, with the tremendous amount of power behind them and synchronous apparatus on the ends of the line, there are surges and other effects going on in that system which we do not know very much about.

C. W. Stone: About bringing out the high-tension leads from very high tension transformers. I think there is a decided difficulty in bringing out the leads of a high-tension transformer. I think there again the three phase transformer comes in, because we only bring out three leads as against six in three single-phase transformers, and wherever we pass through a case there is a weak point. We have six weak points on three single phase transformers and only three weak points on the three phase.

P. M. Lincoln: That applies when the transformers are connected in delta. On the very high tension lines we have the middle of the star grounded and that makes it necessary to bring out only one high-tension lead from each transformer. The other lead can be connected right to the case inside.

C. W. Stone: I meant to confine my remark to the delta connection.

Edward A. Wagner: It seems to be the concensus of opinion that the three-phase transformer is the proper thing, based I believe on the assumption that the secondary load is three-phase distribution to a three-phase motor. In this country the practice of a good many stations is to have three-phase generators, and distribute mixed loads; that is, motors and light; and where they distribute for light the distribution is frequently scattered so that it would not pay to put in a three-phase transformer to furnish the light. In such cases the single-phase transformer

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is far more desirable, because the extra copper required for running the secondary lines would more than offset the advantages of the three-phase transformer. I think, then, that in taking up the question of preference of three phase over single phase, it is acknowledged that the three-phase transformer is more efficient than three single-phase transformers combined, but there are other cases where the condition of operation may possibly determine the necessity of installing single-phase transformers.

A. H. Pikler: Mr. Moody says that the disadvantage of the core-type transformers with butt-joints is that the insulation around the bolts might get damaged. That may be so, but not if the transformer is properly made.

As to the increase of eddy currents due to the milling of the adjoining surfaces. The decreasing of the eddy currents is done, not by interposing a sheet of paper between the yoke and between the legs, as Mr. Moody suggests, but by interposing paper between the sheets of the yoke, or between those of the leg. As to the increase of the magnetizing current, it seems to me that the magnetizing current in a shell-type transformer, other things being equal, is a good deal higher than in a core-type transformer where the surfaces are carefully milled, because the magnetic reluctance in a shell-type transformer on account of the flux, the lines of force, traveling from one plate to the one above, and so on, or from one plate to the adjoining plate in the same plane through an air-gap, is much greater than in a core-type transformer with butt-joints. It seems to me that the core-type transformer with the butt-joints is a great advantage to the customer, because it enables him to repair a transformer in a very short time. For instance, such a transformer even above 400 or 500 kw., if a coil is damaged, may be repaired in four or five hours, whereas in a shell-type transformer one has to pull out every single sheet of the core, and then take the coils out, repair the coil, then build up again the core by single sheets. This causes great delay in repairing. It takes probably two or three days, and with large units repairs cannot be made at the station at all; the units have to be returned to the factory. Whether it is butt-joint or not, I believe that the proper construction for a high-tension transformer is the core type, because in a core-type transformer one can separate very easily and conveniently, either by insulation or by oil ducts the high- and low-tension windings, whereas in shell-type transformers, both the high and low-tension coils necessarily must be supported by one support, and on that support the creeping surface cannot be made large enough to allow a good insulation. It is necessary to put very heavy insulation between the coils and core, between or over the high-tension and low-tension coils. The disadvantage of this is that if there is good insulation, there is retained within the coil also the heat which cannot radiate, whereas between the high- and low-tension coils in a core-type transformer there is

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always circulation through the open duct around the coils. This is not the case with the shell-type transformer. In the shell-type transformer coil there are quite sharp corners on the top and bottom of the coil and at the same point there is the support of the coils. From this it can be seen that at the very point where the construction is mechanically the weakest, it is also weakest electrically, and it is also weak from the point of heating.

E. N. Lake: Irrespective of minute details of manufacture, I think we would probably all agree upon the use of three-phase transformers if we confined that use to distributing systems consisting of a large number of sub-stations interconnected by means of underground circuits. But in the matter of the use of these transformers for interurban railway conditions in which there is a string of sub-stations, any one of which is quite essential to the operation of the road. the danger of interruption to the service would be materially greater in the case of a three-phase transformer than with three single-phase transformers. I have in mind a road some 35 or 36 miles in length, which depends for its operation upon three sub-stations. These sub-stations are equipped with three single-phase transformers, each operating a single converter. One spare transformer was provided, making a total of ten transformers for the system. During lightning or other disturbances upon the system, when some of these transformers went out, it was possible to operate with only 60% of the transformer equipment in service; that is to say, with four out of the ten transformers out of service, the road could still operate. I think that those who are interested in the operation of such roads, where there are not the advantages of the interconnected system and not the protection against lightning of the underground distribution, will hesitate to recommend the three-phase transformers.

H. B. Gear: With regard to the use of three-phase transformers for pole work suggested by Mr. Stone, in view of the possibility of using the open delta system for such installations, the use of small three-phase transformers does not seem to be especially advantageous. The saving thus made by the use of two single-phase transformers instead of three is about equivalent to the saving made in manufacturing cost by installing three cores in one case. Furthermore, so far at least as one company is concerned, the prices quoted for the three-phase units thus far show no saving whatever over the cost of three single-phase units.

As to the larger units, say over 25 horse-power, where it is customary to use three one-phase transformers, where they are mounted on a pole the disposition of the weight is rather more easily effected where there are three single units than with one unit. A 60- or 75- or 90-kw. unit, which would be required for a good many three-phase installations in Chicago, is a very awkward thing as a single unit to set on a pole, unless a plat-

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form of some sort be set to one side, or a separate pole set and a platform put between them, whereas three 20- or 30-kilowatt units can be installed on ordinary hangers by using double arms of a little extra strength, without any platform construction and at less expense of erection.

As to the use of underground three-phase units, the advantages cited by Mr. Stone are undoubted in that the number of joints in the manhole is reduced, but there is the quite material disadvantage that a three-phase unit of 60 or 75 kw. is so large that special manhole covers must be provided to get the apparatus in and out of the manhole, whereas with the single-phase units, either of them which may be damaged can be taken in or out through an ordinary size manhole cover.

Perhaps the most serious objection, however, to the use of three-phase units in a large distributing system is the fact that a full equipment of another type of apparatus must be carried in stock. To a company which is installing and removing every day a considerable number of transformers for both lighting and power purposes, the question of keeping a full quota of all sizes in stock is a matter of great importance. Most central stations have, therefore, found it preferable to use the same kind of transformers for both lighting and power, as they can thus carry a line of three or four of each size in stock and are prepared for any three-phase power installation or for any lighting installation at any time.

A. H. Pikler: I notice that the matter of regulation has not been taken up at all in the comparison between single-phase and three-phase transformers. The regulation of a single-phase transformer is better than that of a three-phase transformer. The regulation depends, especially in the case of power transformers, where the load has a power-factor less than unity, mostly upon the reactance of the transformer. In a core-type transformer the reactance depends upon the length of the leg over which the coils are distributed, the relative distance between the coils, and finally the thickness of the coils. In a shell-type transformer it depends on the dimensions of the coils and the number of subdivisions between the primary and the secondary coils. If we make three single-phase transformers into one three-phase transformer, then, in a core type, we have to use a shorter core and thicker coils, consequently the reactance of the transformer will be greater. In a shell type when combining three single-phase transformers into one three-phase transformer, we have to crowd the coils together, and make them thicker, allowing less intermingling between primary and secondary coils, else the magnetic circuit will grow too big, the weight of iron too great, and the magnetizing current excessive. So from this we can see that the reactance in both cases is greater and the regulation of three-phase transformers compared with single-phase is worse.

Edward H. Wagner: I do not agree with Mr. Pikler on that

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score. The combining of three single-phase transformers into one common unit or on one common magnetic circuit does not affect the reactance of those coils, because the reactance of the coils due to the leakage in the iron is negligible. The internal reactance of the coils is proportional to the area of the path between primary and secondary and inversely as the length. Combining them on a magnetic structure so as to get a multiphase magnetic path does not affect the reactance of each separate coil, and it should not, therefore, affect the regulation, since the regulation is due entirely to the combination of the resistance and the reactance of both primary and secondary coils.

A. H. Pikler: I did not say that the combined flux affects the primary and secondary coils of the reactance at all. I took one single-phase transformer alone and one three-phase transformer alone, a single phase transformer of one-third of the capacity of the three phase and the three-phase transformer the aggregate capacity of three single-phase transformers. If you know what are the factors in determining the reactance of a transformer, it is obvious that in a single-phase transformer those factors are more favorable for a smaller reactance than in a three-phase transformer. The combined flux has absolutely nothing to do with it.

Edward A. Wagner: As I understand Mr. Pikler, his comparison is on the basis of, say, 300 kw. capacity. He makes the statement that if we have a 300-kw. three-phase transformer, and on the other hand three 100-kw., single-phase transformers, that the single-phase transformers connected delta or **Y**, which ever way he pleases, will give better regulation than the 300 kw., three-phase transformer. Now the only difference between the three single-phase transformers and the one three-phase transformer is that the three-phase transformer has the same number of coils combined on a smaller core, and since the core-loss is proportional to the weight, we gain greater efficiency in total output. But as far as reactance of the coils and the resistance and the weight of copper in the outfit, there is no difference between the three single-phase transformers and the one three phase transformer, because the reactance of the coils is the same in either case.

A. S. McAllister (by letter): Mr. Peck says that

On account of the phase relations of the currents, the capacity of each (V-connected or T-connected) transformer must be 15 per cent. greater than half the capacity of the three-phase transformer, with a corresponding increase in cost and losses. There is another serious objection to this (either the T or V) arrangement, for on account of the out-of-phase relation of voltage and current the voltage across the three phases will not remain balanced as the load comes on.

The author's remarks are true when applied to the V-connection, but they must be somewhat modified when dealing with the T-connection. When two transformers are T-connected on both their primary and secondary sides, one of the transformers must be designed for 15.5 per cent. more volt-

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amperes than one-half the rating of the equivalent three-phase transformer, but the other transformer is subjected to exactly one-half of the volt-amperes of the three-phase transformer. If the voltage between the phase leads is E, and the current per lead I, the three-phase transformer must be designed for 1.732 $I E$; one of the T-connected transformers would be designed for $I E$ and the other for 0.866 $E I$.

Two transformers with T-connected primaries and secondaries will transform three-phase power from one voltage to another without voltage distortion equally as well as will two similar transformers used to change power from two-phase to three-phase; even for unbalanced loads the transformation will be satisfactory, provided only that the transformer with the larger volt-ampere rating be constructed with its primary and secondary coils well interspaced.

W. F. Lamme (by letter): The strongest argument against using three-phase instead of single phase transformers is the one of accident to the transformer, but when the installation of transformers becomes very large so that the number of reserve transformers becomes large this argument of accident decreases.

Transformers as built to-day by responsible manufacturers are quite reliable, and the chances of breakdowns are, or can be made, remote. In the case of three-phase transformers this reliability can be increased by the use of more careful design and construction and higher insulation tests, and the customer can still get his three-phase transformer at less than three single-phase transformers will cost him, and the risk of a shut-down in the two cases due to accident to the transformer may be considered as equal.

K. C. Randall (by letter): For quite small units up to approximately 100 kw., or even larger, where interruption may be tolerated, the three-phase unit will doubtless show up well. Where the units are larger and isolated, and especially where continuity of operation is of prime importance, three single-phase units will probably show better in three-phase work. As sizes of 1000 kw. and larger are approached, the three-phase units again come to the front, especially as to installation costs.

As to handling when the station is new, during the course of construction provisions may be made for lifting nearly any size unit which it may seem desirable to install; therefore, the choice of the single-phase unit is not necessarily an essential consideration. If a large growth of power business is contemplated, and if at first it is desirable to install but one or two of the future six or eight units, it may be advisable to use the three-phase units irrespective of their size.

If the station be an old one, it will probably be desirable to adhere to the already selected type of unit, unless the original choice has been subject to improvements, which would warrant the selection of different units. This would mean two different types within the same station, or upon the same system, and probably sacrifice the interchangeable feature.

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The failure of a three-phase transformer or of one of a group of single-phase transformers is about of equal significance in its bearing upon a shutdown. In either case, if operation is delta-delta, switches may be so arranged that the transformer on the faulty phase may be cut out, the remaining two transformers operating in *V* to carry a portion of the load. This applies equally well to the single-phase or three-phase units. Shell type transformers are here contemplated. A failure in any phase of a core type will put the transformer out of service, unless the faulty phase can be opened and isolated. If operation were star on either end, then operation could not be continued until the unit was repaired or replaced. The cost of the three single-phase units with a spare may be called 400%; and the cost of two equivalent three-phase units 500%. The cost of two groups of single-phase units; that is, six transformers, will be 600%. As a matter of fact, it is doubtful if the two three-phase units will actually cost any more than the four single-phase units when they are finally installed, wired up, water-piping completed, and ready for operation, the single-phase unit being arranged so that any three may operate in a bank, and the three-phase units being arranged to operate singly or in parallel, as may be desirable. It should not be lost sight of that the three-phase units have a capacity of 200%, while the three single-phase units have a capacity of but 100%, it being impracticable to use the fourth transformer to advantage with the delta-connected group. However, the four transformers may be connected in open delta, two on each leg, so that a capacity of 13% higher with the same heating effect in the transformers, is obtained. The gain in capacity is in general obtained at the expense of regulation, it being well known that transformers operating in " *V* " or open delta, do not give equal regulation on the three legs of the three-phase circuit.

It would then appear that for good size units, say 1500 to 2000 kw., in stations where considerable power is to be used and a continual growth of business is expected, it will frequently be advisable to employ three-phase units rather than single-phase, as in this way complete new units may be installed one at a time to much better advantage than if single-phase units were used in groups of three. The three-phase unit being the heaviest, it will generally be more difficult to handle, particularly in the case of old stations where crane facilities are very limited; yet it still may seem advisable to install the three-phase unit, making a special effort for this purpose. Side tracks are now generally found near stations, so that the transportation matter is pretty well taken care of.

There is a tendency to ship transformers unassembled, as is done with large generators. If this is done the disadvantage of the additional weight of three-phase over single-phase units is small, and it will only require the attention of an experienced man for a number of days to put together the three-phase units on the premises rather than at the manufacturer's works.

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D. L. Huntington (by letter): For nearly four years the company with which I am connected has been purchasing three-phase transformers for nearly every installation of 150 kw. or more, and is using transformers of this kind in sizes from 150 kw. to 2200 kw. These transformers have been installed on 60,000-volt lines, star-connected with grounded neutral. Under these circumstances there would be practically no advantage in case of breakdown by the use of three one-phase transformers, as the latter could not be used to obtain temporary service.

On all remaining points the three-phase transformer has a distinct advantage; namely, first cost, convenience, simplicity of wiring, space occupied, piping and general expense of drying out, filling with oil and installing. If the large quantities of oil used in transformers be considered a serious fire-risk, the one-phase installation will be much more of a risk than the three-phase on account of the larger quantity of oil required.

Mr. Peck says that with the core-type one- or three-phase transformers there is much less need of providing spare capacity than if the shell type is used. I wish that our experience would bear out this conclusion; but unfortunately we have had all our transformer troubles with core type and none with shell type. I will of course admit that in case of a burn-out the core type is much more readily repaired; but in that very fact lies the reason of its inferiority as against trouble, for the looseness of construction, which so readily admits of the removal of coils is the cause of most of its failures, so far as our experience goes.

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Discussion on "Potential Stresses as Affected by Overhead Grounded Conductors," at Chicago, May 24, 1907

(*Subject to final revision for the Transactions.*)

P. M. Lincoln: I consider Mr. Jackson's paper an interesting discussion of a very important topic. It is, as Mr. Jackson admits, purely a theoretical discussion of the amount of protection which may be expected from an overhead grounded wire. Many transmission line operators believe that this overhead grounded wire has no virtue; others believe that it has a great deal of virtue. I expect that there are representatives of both camps present and I hope the discussion will be complete.

Dugald C. Jackson: This paper relates to a subject that was discussed at the last Niagara Falls meeting of the Institute. It was there somewhat vigorously discussed on both sides. It seems to me that the art has progressed a good deal since that meeting, and the iron tower has become very much more important as a support for transmission lines than it was then. At that time one could consider for the larger portion, at least of existing plants and perhaps the larger portion of plants then under construction, that the wires were erected upon wooden pole lines with wooden cross-arms, and that one could rely to some considerable degree upon the insulation of the wooden parts supporting the insulators. At the present time one must look upon the future transmission lines, and even the most important transmission lines of the present day as they are being built, as lines supported upon iron towers and therefore lines for which one can only rely upon the insulators themselves to give the insulation. It seems to me that the latter condition, as compared with the old wooden pole lines, makes this discussion of the overhead grounded protective wire quite a different matter. When we had the advantage of the wooden insulation to assist the overhead insulator, anything which brought the potential of the earth closer to the transmission line, as would be the case with the overhead grounded conductor, was inclined to increase the probability of a breakdown of the insulator, for the reason that it reduced the amount of added resistance to breakdown by reducing the length through the wood. I think that that effect has to a large degree been the effect that has led many people to object to the overhead grounded conductor, especially when added to the fact that the overhead grounded conductors were frequently put up very badly and caused trouble on account of their poor mechanical structure. However, even badly put up as they were of old, and notwithstanding the condition by which (with the wood pole line) the breakdown stress after the cloud discharge had occurred was increased on the insulators, the fact that the grounded conductor made a secondary circuit which in a certain extent abates the surges (as was pointed out, I think, by Mr. Steinmetz at the Niagara meeting I refer to), apparently gave the grounded conductor considerable value.

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Now, when we come to the situation where the wooden insulation is out of the account, a reduction of perhaps 50 per cent. of the electrostatic stress on the insulator is well worth while, as Mr. R. P. Jackson points out. I doubt whether the reduction in the direct electrostatic stress produced by the grounded wire would be so great as 50 per cent., but if the reduction is as great as 25 per cent., which I have been able to convince myself it might be, I think it might be well worth obtaining in the case of a line built upon iron towers. Perhaps the reason that Mr. R. P. Jackson and myself differ as to the amount of reduction of the stress that comes about by a single overhead grounded wire lies in the fact that he has in his mathematical formulas taken no account of the disturbing influence of the metal line conductors themselves, while I have tried to do that, and when one takes three phase wires six feet apart and puts a single grounded conductor a few feet above them, the influence is not nearly so great as one would imagine he would obtain from an examination of these equi-potential curves of Mr. R. P. Jackson's paper. This is by no means a criticism of Mr. R. P. Jackson's paper, which I think is a most suggestive paper and which comes at the very pertinent moment when the construction is changing from the old wood pole line construction to the preferable iron tower construction.

D. R. Scholes: I am hardly qualified to speak on this subject, so far as potential stresses are concerned, but I come in contact quite a good deal with the problem of the grounded conductor in building transmission-line towers, and it is interesting to learn how great the range of opinion is regarding the question. In some very long lines using steel towers no overhead grounded wire has been provided. This is true with regard to the lines of the Niagara, Lockport & Ontario Power Company. A certain amount of trouble has been reported with the top insulators in these lines, presumably due to the absence of the overhead grounded conductor. In some cases, one, two, or as many as three overhead grounded wires are provided for in the towers; in other cases there are guards placed over the insulators, or lightning-rods are provided, projecting considerably above the top of the insulator. In one installation now under construction in South Carolina, three overhead grounded wires are installed, placed in a sort of umbrella arrangement over the power wires, which seems to be the most extensive attempt at protection against lightning or static discharges by means of grounded wires that has yet been made.

The usual idea that occurs to the tower builder regarding the effectiveness of the overhead grounded wire is that if it is placed at such elevation that a plane passing through it and making an angle of 45 degrees with the horizontal lies above all the power wires, the power wires will be protected. Where this idea gets its foundation I do not know, but it comes to us very often, and we are often called upon to place the grounded

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conductor supports in this way. Almost without exception the towers that are now being built, to my knowledge, are provided with ground wire support in such way that if the ground wire is not strung at the outset it may be strung later, if developments indicate that it is needed.

H. C. Hoagland: My experience has been chiefly in Michigan where we have had trouble with lightning. We ran a grounded wire on the under side of the transmission wire, and then noticed that the lightning discharged down to the poles, splitting them. After putting on the ground-wire it practically eliminated that trouble. On the line from Jackson to Battle Creek two ground-wires were used on the top arm, one on each end of the arm, and that practically relieved the trouble in that case. In Illinois a part of the line is equipped with the ground-wire on top of the pole; that has only been in service about a month, but there has been no trouble on that line. On some of the other lines there has been serious trouble; they have been shut down four or five times in the last month. Arrangements are now making to put the ground wire on top of the poles as fast as it can be done. There is only one ground-wire, but on new construction perhaps it would be best to install two ground-wires.

P. M. Lincoln: I would like to ask Mr. Hoagland if his experience has demonstrated that the ground-wire is of positive value in preventing lightning discharges?

H. C. Hoagland: It has been demonstrated beyond any question of doubt in my mind that it is a great benefit even on the wooden poles, as in the Michigan case. We had several cases where four or five poles have been split into slivers. Putting on the ground wire did away with all that trouble.

R. P. Jackson: In regard to putting a lightning-rod on top of the tower. In some cases that feature results for good. Any conductor carried up above the insulator which the lightning may strike if it comes that way and which will also relieve the stress through the space, that is, the electrostatic stress through the atmosphere, will help matters, but it is not a complete relief. I have heard of cases where devices of this kind have been put up and a partial relief obtained, the number of broken insulators was much less, but that number could be still further decreased by putting up grounded lines which would prevent the transmission lines from accumulating such a static charge as they would otherwise. Of course if not released such charges will go to sub-stations and get into the generating stations and transmitting apparatus, but probably it will pass off at the next insulator. The greater the charge the greater the tendency to get off on a near-by insulator.

The result in every case has been the same; that is, the top of the pole has burned off, down to the ground-wire. Last year we built five or six miles of line, using a new form of construction. The ground-wire on one line was placed on top of the pole and the conductors arranged on two cross-arms below.

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In the other case, the ground-wire was placed on one pin of the upper arm. There were numerous storms last season, and so far this year there have been four of more than usual severity. It may be only a fortunate coincidence, but the fact remains that none of these lines have ever caused us the slightest trouble, although we have ample evidence of severe lightning discharges along the route. About two weeks ago one of our employes saw the lightning actually strike a portion of this line about four pole lengths from No. 5 sub-station. The only damage was a punctured high-tension transformer terminal which caused a temporary short-circuit and threw out the circuit-breaker. I am thoroughly convinced that had this discharge taken place in the neighborhood of some of our old lines we should have undoubtedly lost a pole and suffered consequent interruption.

I am pretty thoroughly satisfied from my own experience that the grounded overhead conductor is the only practicable method of preventing insulator trouble due to severe atmospheric disturbances. I believe that the grounded conductor should be of a fairly large cross-section, not less than No. 4 gauge, and preferably stranded. It should be of the very best quality of annealed iron, thoroughly galvanized, and should be grounded at least on every other pole.

It will perhaps be of interest to tell that our type V arresters, as we now have them arranged, are working perfectly, and since their installation we have not lost five cents' worth of apparatus due to the failure of the protective devices. There is a slight tendency for the cylinders to weld together under a very severe discharge, but careful inspection will prevent any serious trouble arising from this cause, since it is our experience that very seldom do a sufficient number of cylinders weld together during one discharge to cause a breaking down of the arresters at normal potential.

James Lyman: I was in Montana about a year ago and looked over some of the transmission lines, including the Madison River and the Big Hole transmission line. These transmission lines were put in about six or eight years ago. The Big Hole line is 15,000 volts, two three-phase transmission lines on one pole line. This line is about twenty miles long. It goes over a divide in the mountains where particularly severe discharges take place; these discharges are so severe that when the pole line was built the tops of nearly all the trees showed indications of having been struck. There was some hesitancy about building a pole line there, in fact all sorts of interruptions were expected. To guard against trouble, for three or four miles of this divide a barbed wire was run along the tops of the trees that had been struck by lightning; on each side of the pole line. Three barbed wires were also put on top of the pole line, one on the extreme ends of the upper cross-arm, which also carried one conductor of each of the two transmission

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lines, and one barbed wire on the top of the pole and grounded the wires at each pole. As an experiment, to see what the effect of these overhead grounded wires was, a small switch was put into each of the ground-wires, at the foot of the poles, so that all of them could be opened during a thunder storm. The lightning arresters were placed in the usual way at each end of the transmission line. The storm effects were soon watched after the transmission was put in, and the discharges of lightning could often be seen coming down to the barbed wire on the tops of the trees, also the barbed wire on the tops of the pole line. The lightning-arresters were not particularly active; there was not very much going on, and for some six or eight months during the whole season there was no trouble. During one pretty severe storm, the switches on all the grounded wires were opened the entire length, so that the grounded wires were entirely disconnected from the ground, just during one storm. The lightning arresters discharged almost continuously, and there was anxiety lest some of the apparatus should be injured. It was not, however, during this storm, but it was a practical demonstration of the value of these overhead grounded wires. In the rebuilding of the Madison River transmission, which is about 50,000 volts pressure and about sixty miles long, it was planned to have a liberal size grounded wire, grounded every three or four poles, over the whole line, hoping thereby to get as good service there as that on the Big Hole line, which ran through a district where far more severe storms occurred.

From my experience the transmission lines which are protected by overhead grounded wires are more free from troubles than those which are not. Of course lightning-arresters also add greatly to the protection of the system, and I would recommend them in all cases.

P. B. Woodworth: Lightning protection brings to mind an experience I had with barbed wire. We had an equilateral distribution and it became necessary to put up some kind of protection. A single barbed wire was placed above the equilateral triangle. To specify barbed wire is one thing, and to actually put up a barbed wire is quite another thing. After we got it up it apparently worked well. But once—more than once, once in particular that I remember—the wire broke. Stranded barbed wire is usually wound on a reel. When that wire broke it wanted to get back on the reel, and it went round and round those three wires, time and time again, and one can imagine the situation when it became necessary to cut down a barbed wire so located.

W. L. Abbott: If I might be pardoned for introducing a reference to direct-current low-tension matters into this meeting, I will tell of an experience which we had in the Harrison St. power house of the Chicago Edison Company, which at that time supplied direct current only to an underground system.

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During one particularly severe thunderstorm we noticed at every flash of lightning a flash at the commutator brushes, and at the instant of this discharge at the brushes the dynamo was so charged that the dynamo tenders would receive severe shocks if they were in contact with the machine, although ordinarily the machine could be handled without any discomfort whatever. During this storm several switchboard instruments grounded to their frames and burned out. We thought at the time that the lightning had struck a building in the city, followed our conductors to the power house, and had gone to ground through the iron framework of the building. We decided afterward, however, that the lightning had struck the iron smokestack of the power house and had finally found a ground by jumping from the framework of the building to the generators and switchboard apparatus, and then again to ground through the underground network.

W. B. Jackson: It has long been the feeling among a large portion of men operating electric transmission lines in regions where severe electrical disturbances occur that well installed grounded conductors when properly placed are a very material protection. Many have figured out reasons for this protective characteristic from a more or less practical standpoint. Mr. R. B. Jackson now presents a careful theoretical analysis of the situation as he sees it. This analysis, coupled with the practical results that appear to have been obtained by use of the grounded conductor, strengthens tremendously the argument in favor of the installation of this class of protection. To-day it seems there is very little that is being undertaken in practice in the field of alternating-current transmission of power that can not be greatly assisted by a careful consideration of the theory. In fact it almost seems that the old time condition is being reversed in these matters and that theory must now "blaze the trail" and practice finish the clearing. The old complaint that grounded conductors are more trouble than good is now a thing of the past, for it is entirely practicable to install properly located and grounded steel wires so that they will give much less trouble than the line they protect.

There is a fine opportunity for study upon electric lines affected by destructive electrical phenomena, by the use of the oscillograph. It would seem that such work when undertaken upon regularly operating lines should have something of the same zest as the photographing of the tiger in its native jungle. In fact it would seem that extreme persistence and patience and courageous endeavor, besides a good deal of experience, would be required to get oscillograph records of all of the phenomena involved. Mr. R. B. Jackson has evidently given this matter of grounded protective conductors careful study, but he has other things that must demand the greater part of his time, and the complete study of this subject is one that may worthily occupy the complete time and attention of careful investigators for an extended period.

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This is a splendid subject to be taken up with the assistance of the large income of the Carnegie Institution of Washington, D. C., and one or more of the able scientists of that Institution might execute the work. I suggest that the American Institute of Electrical Engineers throw its influence toward such an end.

George Hayler (by letter): I am much interested in Mr. Jackson's paper. Mr. Jackson, while treating the problem simply from the theoretical standpoint, confirms absolutely our actual experience with high-tension lines.

We have been operating a power system about forty miles long, at 33,000 volts, 25 cycles, for something over two years, and this will be the third season for electrical disturbances.

The original lines were built in the form of an equilateral triangle, with the apex pointing upward, the ground-wire running the entire length of the system, and located about three feet below the cross-arms. This form of construction while exceedingly economical, is, in my opinion, the worst possible arrangement that could be devised. Virtually all of the interruptions to the service, caused by atmospheric disturbances, have resulted from the failure of the top insulators, showing beyond a doubt that the greatest potential strain occurs at that point.

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Discussion on "Forced-Oil and Forced-Water Circulation for Cooling Oil-Insulated Transformers," at Chicago, May 24, 1907

(Subject to final revision for the Transactions.)

C. W. Stone: Mr. Chesney points out one thing that should be considered in two ways, the extra floor space required. It is true that if one considers the space taken by the condenser outfit for cooling the oil and the extra pumping apparatus necessary, more floor space may be required, but that extra floor space can usually be found in most stations. The space necessary for the cooling apparatus, the pump and condenser, is not so great as the space occupied by the transformer, and they can usually be put away in some corner in the station. Also in several cases I have found it advisable to install this cooling coil, not in a part of the station but, say, in the tail-race, using the water from the turbine to do the cooling. There is not, therefore, the complication of extra pumping facilities; there would be one set of pumps similar to those that are ordinarily used for forced water circulation in a water-cooled transformer.

Another important thing to consider in connection with the forced oil-cooling of transformers is head-room. Most of the attention given in this paper is on the score of shipment. This is a serious matter only in the very largest size; but frequently in the design of a water-power station where the station is built right on the rock, considerable excavating is necessary in order to provide transformer compartments; and where the rock is solid, the expense is considerable, and if one can dispense with any head room at all it is well worth saving, even if it is necessary to incur the expense of extra pumping facilities.

It is also true that the oil is under moderate pressure; therefore very little trouble should be experienced from the pumping outfit with forced oil circulation and separate cooling. That is, the troubles experienced are not nearly as serious as in most central stations where the oil has to be pumped anyway, and frequently at much higher pressure. An ordinary small, low-pressure, motor-driven pump is about as simple a device as can be put in a station.

W. S. Moody: One little detail that Mr. Stone did not speak of in connection with forced-oil designs is perhaps worth mentioning; namely, the incidental advantage attained when it is possible to locate the cooler in the tail-race of a generating station. Here, having practically an infinite quantity of water compared with what is actually needed for the cooling, there is no perceptible rise in temperature of the water.

When the water for cooling is pumped through the cooler it is hardly ever practicable to use a larger quantity of water than that which will be raised about 10 degrees in temperature; consequently the average temperature of the cooling water, when the cooler is in the tail-race, can be considered as five degrees less than when water is pumped through the cooler.

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The result is either a reduction of five degrees in the actual temperature of the transformer under full load, or the possibility of using a cheaper transformer having the same actual temperature as one cooled by artificially circulated water.

A. Henry Pikler: The idea of cooling transformers in this way is not recent. The reason for the increasing use of this method of cooling is due to the development of very large units, which require special devices for keeping the temperature within the proper limits.

The dissipation of heat in transformers with forced oil circulation is primarily due to convection and not to conduction or radiation. Consequently the speed with which the oil is forced through is of vital importance; the greater the speed up to a certain limit, the better the cooling and therefore the smaller the apparatus for a certain given rise in temperature. Therefore the statement: "The total saving in the transformer proper will vary from 15 to 25% depending upon the size of the transformer," has very little value unless the speed be given.

As in all apparatus which has forced cooling, so with this one—the danger arises in the case of breakdown of the cooling arrangement. The density in the copper and the iron, and consequently the heat generated, is higher in this than in transformers cooled by other means. If the cooling arrangement gets out of order, the former kind of transformer can be operated without forced cooling for fewer hours than the latter; this is certainly a disadvantage in the former system.

W. B. Jackson: There seems to be one advantage here which has not been pointed out. In this system of water cooling transformers the possibilities of trouble from leaking water pipes may be entirely eliminated; in other words, instead of there being pressure tending to force the water into the oil it is entirely practicable so to arrange the system that the water will be drawn through the cooling coils in such a way that the old danger of water getting into the oil and in that way short-circuiting the transformers, is entirely overcome.

W. S. Moody: I was just referring to this particular possibility of trouble. As soon as the idea of using the forced-oil method of cooling occurred to us, this source of danger naturally presented itself as something necessary to guard against. We do so by simply arranging that the water and oil pressures in the cooler be such that the leakage will be in the direction from the oil to the water, so that if there is any little leak the result is simply a little loss in oil. There is no possibility of water leaking in the other direction.

P. M. Lincoln: There is one disadvantage that occurs to me and one which no one has yet mentioned, and one which the oil transformer designer realizes more than anything else; namely, that oil is the hardest stuff there is to keep where it belongs; and the more piping, etc. there is to convey this oil around the more danger there is of getting leaks and a con-

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dition which might be best designated by the term "sloppy". That is, I think, one real objection to the scheme of having forced oil circulation rather than the present. It is undoubtedly cheaper; that is to say, there are bound to be less materials used with a properly designed oil circulation than if the oil is allowed to circulate itself, and efficiency can be improved for the reason that with a more efficient means of carrying off the heat there is bound to be an improvement in efficiency. As against that there is this condition of having a greater tendency to leakage and having an auxiliary apparatus which the modern operator, if my experience leads me to judge aright, tends to avoid rather than to court.

S. M. Kintner (by letter): Mr. Chesney treats only briefly a subject about which a great many interesting things can be said. In his brevity he has left at least one point that needs to be qualified. He says: "The density of both copper and iron can be increased for the same temperature, etc." The above is true for the higher frequencies only so far as change in density in the iron is concerned. It is not the loss and consequent temperature in the iron that prevents a greater magnetic density for the lower frequencies, but it is the increased magnetizing currents that would follow working at any greater magnetic intensity.

There are several characteristics of oil that must be borne in mind for a thorough appreciation of the various methods employed in cooling oil-insulated transformers.

The oil is an extremely poor conductor of heat. I have repeatedly noted temperature differences of 60° cent. in a column of oil only 6 in. tall. The heat was of course applied at the top of the oil column. The above condition is one that existed after several hours' operation so as to insure a final balance of temperature conditions.

The oil carries heat by convection currents only and consequently has a tendency to pass upward only. This makes it extremely important to see to it that no dead oil pockets exist in the transformer, as otherwise a hot spot of 50 degrees or 60 degrees cent. excess might exist locally in the windings.

The oil film heated by contact with the hot coil tends to rise along that face. This oil film is very thin and exceedingly difficult to measure. Temperature measurements taken by thermometer laid alongside of the coil face will give an incorrect reading, unless specially guarded against the oil flow. Temperature differences of five or six degrees have been noted within one-eighth of an inch of the coil face when explored with a point thermo-couple.

Oil acts simply as a heat ferry in taking the heat from the inside of the transformer to the place where it can deliver this excess heat to a dissipating body. It is, therefore, evident that large "docking facilities" are very essential in order to prevent congestion of traffic of the little heat ferries; that is to say,

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ample contact area between the oil and the source of heat and again between the oil and the dissipating body is required.

All the above points should be given thorough consideration in the development of the various systems of transformer cooling. The following brief discussion gives the principal points involved in the best known methods of cooling.

Self-cooling, oil-insulated transformers. Self-cooling transformers give up their heat to the surrounding air and the improvements in these, in so far as cooling is concerned, have been improving the facilities of the oil for loading and unloading the heat. The unloading facilities have been improved by using corrugated cases, by using cast iron ribs and pins, by using larger tanks (particularly taller ones as the top of a transformer tank is by far the most effective radiator to the air on account of its higher temperature above air) and lastly by using tubes, containing a certain proportion of volatile liquids that will vaporize on being heated slightly, and consequently keep the tubes at almost uniform temperature throughout their entire length.

All of the above devices have sought to get more contact area of heated air with tank or body which is to deliver the heat to the air and to get more oil contact surface with the tank or as equivalent.

Forced water-cooled transformers. As the speed with which the oil moves is directly dependent upon the temperature difference of the oil, it is evident that more rapid oil movements will be obtained in the water cooled transformer with its chilling water coils near the top of the tank than in the self-cooler. The increase in oil speed is a very desirable thing, as it sweeps out the oil vent ducts in the transformer and keeps them supplied with fresh cold oil. The speed of oil movement is dependent upon the temperature difference between the hot oil and the cold oil in which it is immersed. This speed can never exceed a certain maximum because of permissible temperature differences being limited to fairly small values, possibly not more than 20 degrees cent. should be allowed. It is evident therefore, that this method of cooling reaches its limits from the lack of sufficient speed of oil movement.

There have been some instances of cooling in which the transformer tank was immersed in running water. This is but a modification of the above method and has given satisfactory service in a number of places.

Care must be exercised in using these methods to prevent leaks of water into the oil, as a trifling amount of water will cause serious damage.

Moisture will sometimes condense on the surface of the water-cooling pipes at the points where they enter the transformer; this is caused by their temperature being lower than that of the surrounding air and is readily prevented by lagging the pipe so as to prevent its coming in contact with the air inside the transformer tank.

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Frequent inspection of the water coils is necessary to make sure they are not collecting sediment on the inside that would prevent water flow.

Forced-oil circulation transformer cooling. This method, which involves the drawing off of the hot oil from the top of the transformer tank and the cooling of the oil before it is returned, has its principal advantage in the increased rate of oil movement that is possible.

It has an additional advantage in that the cold oil can be delivered directly in the transformer against the copper and iron.

It is possible with this method of cooling to increase the rating of the transformers from 15 to 30 per cent., depending

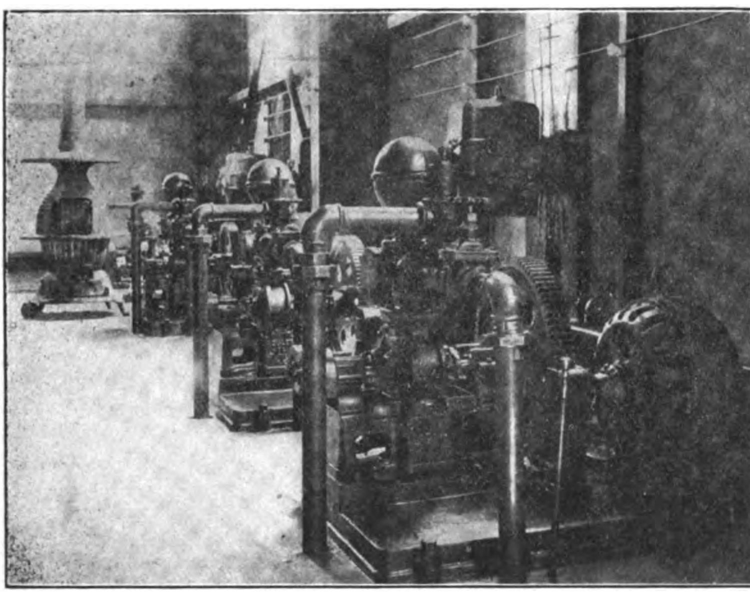

Fig. 1.

upon conditions involved in individual cases. A fairly accurate idea can be obtained of the amount of cooling possible with this method if the figure 9 gallon-degree-min. per kilowatt is taken. From 25 to 30 degrees of cooling is possible if sufficient radiator capacity can be obtained. There is no difficulty in getting this if the radiators are immersed in cool running water.

Figs. 1, 2, and 3 illustrate an installation of the above kind at DeCew Falls, near St. Catherines, Ontario. In this plant, five 2500-kw. oil-insulated transformers are each provided with a forced-oil cooling system. In this installation each trans-

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former has an independent cooling system which is in no way connected to the others save in the source of electric supply of the individual motors.

Rotary pumps driven by induction motors, all arranged on the same sub-base as shown in Fig. 1, circulate the oil at the rate of approximately 90 gallons per minute. The oil is drawn from the top of the tank by a pipe which enters the tank through the cover and dips down into the oil to a depth of approximately eight inches below the surface. The oil after passing through the pump passes to the cooling coils. Fig. 2 is a view of one of the coils taken as it was being lowered into position in the

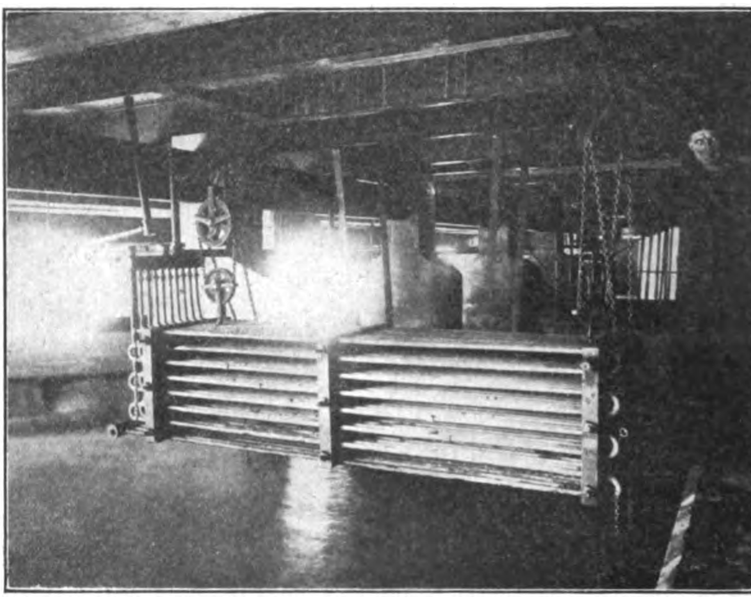

Fig. 2.

tail-race of the plant. The oil, after passing through this coil where its temperature is lowered to within a few degrees of that of the water, is delivered directly against the bottom of the copper coils of the transformer. The bottom of the transformer is partly closed so as to force the large part of the cold oil to pass upward through the transformers. The rest of the oil passes up around the outside of the iron and assists in carrying away the heat due to the iron loss.

A check-valve is placed in the pipe at the inlet to provide against possible danger of draining all the oil in the event of the cooling coils being torn away by ice or drift in the tail-race.

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The pressure of the oil is always in excess of that of the water, and consequently a leak would cause a loss of oil but no inflow of water. A very small oil leak is readily noticeable in the water, so that the system seems amply safeguarded both as regards safety of operation of the transformers and against loss of oil.

Fig. 3 shows several of the cooling coils in position. This view was taken at a low-water period during the time of erection.

These cooling coils have been in service about a year and a half and have given very good service. No trouble has been experienced with leaks in the coils or with troubles from driftwood or ice. No difficulty has been experienced in starting

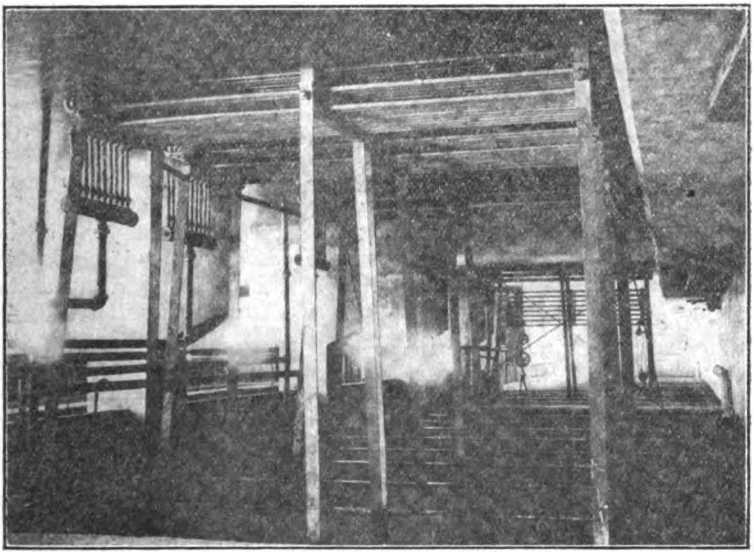

Fig. 3.

the cold oil after standing idle for hours in the low temperatures that exist in Canada.

It is possible to use a single pump for installations of this kind in place of the more expensive arrangement shown in the views above, provided this pump draws its hot oil from a common tank which fills from overflow outlets in the various transformers. An arrangement of this kind makes a safe operating condition though hardly as satisfactory as the individual pumps.

There are some places, where water is not available, where the circulation of the oil through radiators which dissipate their heat to the air will be found the best available. This air cooling can be assisted by fans directed against the radiators.

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A. H. Babcock (by letter): Some expensive experiences with cracked or punctured water coils in high-potential transformers caused me, several years ago, to discuss with the manufacturers, the oil circulation cooling method. At that time there had not been reported sufficient troubles of this kind to make the matter of enough importance to force the factories away from a manufacturing standard method.

In making the installation, it is suggested that in addition to the reversed connection of the water circulating pumps, as shown in the author's sketch, the condensers be placed in such position relative to the oil piping that with all pumps stopped, the oil pipes in the condensers will be under a static head. Under no conditions should it be possible for the water to rise into the oil-circulating pipes.

To avoid condensation within the transformer case, the oil should not be cooled below the temperature of the air in the case. A pair of thermometers, one in the air of the transformer case, the other in the oil, provided with contacts within their bores, and connected bridge fashion, could be used to give an alarm when the temperature of the oil falls too low. Similar thermometers with a single pair of contacts have been used on the Pacific coast for several years, to signal excessive oil temperatures.

It is suggested further that a system of air cooling the oil be developed for use in arid regions where water is difficult to obtain.

Broadly considered, in my opinion the disadvantages named by the author are of small importance compared with the obvious advantages.

M. C. Canfield (by letter): It seems to me that some of the advantages incidental to the forced-oil circulation system have been overlooked in the paper under discussion. In the forced water circulation type, there is occasionally trouble from sweating of the water pipes at the top of the transformer case, and many transformers are built with heat-insulating coatings on the upper portion of the cooling pipes where they are above the oil. This sweating is, of course, due to the great difference of temperature between the air in the top of the transformer case and the water pipes. This difficulty does not occur in the forced-oil circulation system.

Any leakage which may occur in the cooling coils of a water circulation transformer, results in the escape of water into the transformer case, and consequently, into the oil. In the case of the forced-oil circulation it is a simple matter to keep the oil in the condensers (?) at a higher pressure than the water, so that any leakage which may occur will be a leakage of oil into the water, and not vice versa.

Mr. Chesney refers to the possible reduction in height of transformer obtained by the use of forced-oil circulation, but suggests that the total floor space required will be increased because of the space required for the cooling apparatus.

In the case of the transformer with forced-water circulation,

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the transformer-case must be of a size to contain the transformer, and to provide ample space around it for the circulation of the cooling oil. This space must be large, to provide for the descending currents of cooled oil, and as the pressures acting to produce such currents are very small, being due to differences in specific gravity of the oil only, the currents are slow and require much space.

In the case of the forced-oil circulation the situation is completely altered, as it is only necessary to provide for the flow of oil in one direction within the transformer, the flow in the opposite direction taking place through the piping of the cooling system. It is desirable to make the transformer case fit quite closely around the transformer, in order to throw the oil current against the transformer as much as possible. It would therefore seem possible materially to reduce the floor space occupied by a transformer equipped for forced oil-circulation. This reduction of floor space should materially offset the space occupied by the auxiliary cooling apparatus, especially with large installations.

G. Percy Cole (by letter): Occasions may arise in very large installations where it would certainly be good engineering to adopt transformers cooled by forced-oil circulation, but taking everything into consideration, these instances are exceedingly rare, and it will usually be found that the water-cooled type will fulfil the requirements satisfactorily in spite of its slightly increased size.

The water-cooled type appeals more favorably to engineers for the following reasons:

1. Because it has passed the experimental stage, and proved its reliability—even in the very largest units at present installed.

2. The simplicity of the cooling system. The majority of power houses, where very large units are installed, are hydro-electric, and in such cases the water required for cooling costs next to nothing; the piping being reduced to a minimum, since a gravity system will replace pumps in a great many cases.

3. Less liability for the oil to take up moisture. We hear of extremely few instances where trouble has resulted from cooling coils leaking. The adoption of cooling coils of seamless copper tubing, and the great care bestowed by manufacturers in building and installing this tubing have resulted in almost absolute freedom from the trouble of water getting into the oil from the cooling system.

With the adoption of very large units and high voltages (60,000 to 80,000 volts) it is absolutely necessary that the oil surrounding the coils be kept free from moisture. Where oil has to be circulated through the transformer, out through piping, through large cooling systems and pumps external to the transformer, there is much greater danger of getting water into the oil than with water-cooled transformers. Even if a gravity water-cooled system cannot be employed, and pumps have to be

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used, water circulation shows up more favorably even if only taking into account the amount of liquid circulated; for since oil has a specific heat of approximately half that of water, it is quite evident that at least twice the number of gallons per minute for the same cooling effect would have to be circulated if oil circulation were adopted than if water-cooled had been used instead.

D. L. Huntington (by letter): The advantages which forced oil would have over forced water appear to me as follows:

1. The movement of the oil, being guided specially to those portions of the windings or core which most need cooling, should be much more effective than with forced water, and for this reason higher efficiencies and longer life should be had for a given combination of copper and iron; or the equivalent of a larger output with the same efficiency and life.

2. In large or comparatively large installations there would probably be a saving in first cost; but on small installations this is very doubtful.

3. Where clean water is not obtainable for forced water transformer coils the gradual clogging up of the coils is inevitable, and I know of no effective means of cleaning them thoroughly. Under such conditions the forced oil method becomes almost necessary where the installation is to consist of large units otherwise the use of smaller units of the self-cooled type would be the only practical resource, and that a very expensive one. not only in the transformers, but in the buildings and wiring.

4. In case the forced water type of cooling coils are used which enter and leave the top of the transformer, there is danger of freezing if the transformer is temporarily out of use, and the only practical plan which we have been able to find is to blow the coils out with compressed air. The forced oil system would be easy to drain of water on such occasions. This advantage would not apply to those forced water transformers with bottom inlet and outlets, upon which I have for some time insisted, and which are of course readily drained.

Disadvantages

1. For the forced-oil system some measure of attendance, comparatively regular and frequent, would be absolutely necessary. This would mean a greatly added expense in many plants, such as our's for instance, where we have numerous sub-stations of from 150 to 1500 kw. capacity in a mining country, where the only attendance now required is for a few minutes once a day.

2. With forced-water transformers it is usually possible to obtain water of steady flow and under the required pressure at small expense, and the cooling is therefore very simple, and consequently, very reliable. The forced-oil system is much more complicated and cumbersome and much more likely to get out of order, and to assure reliability equal to the forced-water system, a considerable part of the circulating apparatus should be in duplicate.

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3. My experience is that in case of a burn-out in a high-tension transformer the oil usually becomes so carbonized as to be unfit to use again until it has been carefully filtered. In such a plan as that shown in Mr. Chesney's paper, the pumps would immediately distribute this carbonized oil to all the uninjured transformers, a really serious matter. A similar effect would be had if a water leak developed. As an insulator, all the oil would, to some extent, deteriorate, and would all have to be dried. With the other system the oil of one transformer only would probably have to be treated.

4. To remove these objections to some extent, forced-oil coolers could be installed for groups of transformers. This only lessens the objection, however, and adds materially to first cost and operating cost.

5. Furthermore, if any moisture is carried into the oil in the forced oil plan, the oil carries it to the plates in the transformer where it will be most likely to do harm, whereas moisture may accumulate in appreciable quantity in the bottom of a forced water transformer without doing damage.

Generally speaking, unless the objections regarding spreading of damaged oil through the undamaged transformers can be overcome in some simpler manner than by having a separate cooling plant for each unit, I think the advantages of the forced oil system are distinctly over-shadowed by its disadvantages. Perhaps some ingenious and simple method may be devised to shut off the oil circulation automatically from a damaged transformer. Then, in that case, there are many installations where the size is of some moment, in which the forced oil cooling will be distinctly the best to adopt.

W. F. Lamme (by letter): There are certain cases in which it is better to cool the oil in the transformer through circulating oil through cooling coils in water than by circulating water through cooling coils in oil. In a water power plant an abundance of cool water is always at hand for cooling purposes, and there seems no good reason why these cooling facilities should not be taken full advantage of. If ample cooling coils are placed in this water, and oil from the transformers is circulated through coils in this water, the cooling effect is better than if this water is passed through cooling coils in the transformers. Besides, the type of pipes through which the oil is circulated can be made and installed by any good pipe fitter and can be made as extensive as the operation may demand, whereas, in the case of the ordinary internal coils these coils are made by the manufacturers to suit the case and core of the transformer and are difficult to increase or modify.

In the case of oil circulation the pressure is applied to the oil and not to the water. This lessens the liability of water getting into the oil due to this cooling apparatus. We know that many cases of accident have been due to leaky coils in the case of water cooled transformers.

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Since external circulation permits larger cooling facilities of course oil circulation can be made to give much more reserve where the same core and case are used. This is a very important matter in plants having a high peak load.

In warm, dry climates, such as the San Joaquin and Sacramento valleys of California during the dry season of mid-summer, it has been demonstrated that external circulation of oil cooled by water dripping over the cooling pipes in the open air has a very marked advantage over water circulation through internal cooling coils. We have no definite figures on hand showing these advantages, but a simple observation makes it evident that the advantage exists.

Wm. McClellan (by letter): In discussing this question it must be assumed that all mechanical features would be worked out so as to be thoroughly reliable. The expense of either system will vary according to the details and size of the installation, and in cases where there is a large number of transformers a considerable difference in the cost of the two systems might be found.

From his present point of view, the writer would be rather disinclined to favor the adoption of a forced-oil system. Such a system does certainly increase the risk of getting small amounts of moisture in the oil, and it is well known from recent experiments how much damage a very small amount of moisture can do in transformer oil.

In the forced-water type it is possible to keep all joints, except those which are brazed, entirely outside of the transformer case so that there is no risk from water except in case of a serious accident. The circulation of oil in the forced-water transformer is very uniform and takes place very quietly. The result is that moisture which accumulates gradually is very likely to be found at the bottom of the transformer and is undisturbed by the oil circulation; this would probably not accumulate to as great a degree in the forced-oil transformer.

One point in favor of the forced-oil transformer is the ease with which it permits of oil treatment. It looks very much as voltages increase as if we might come to the time when regular treatment of transformer oil would be imperative. In case of the forced-water transformer, this means, removing it from the line, taking out the transformer oil, giving it some sort of a drying and purifying treatment, and then returning it to the transformer. With the forced-oil circulation it would be entirely unnecessary to take the transformer off the bus bars since the oil could be treated at some point in the circulating system without affecting the operation of the station.

This will be all the more important should we ever arrive at the sub-station with all the transformers out of doors. As it is, with high tension transformers inside of buildings, there is some risk in removing oil from the transformers and allowing them to stand even for a few hours without oil if the cover must be taken off for any reason. It is very remarkable how quickly

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the insulation resistance of high tension transformers will change gradually under these conditions.

A. L. Mudge (by letter): The extent to which forced-oil circulation for transformers comes into use will depend largely on the manufacturing companies. If they can quote materially lower prices per kilowatt, while making the same guarantees, it looks as if forced-oil circulation would almost entirely displace forced-water circulation for large installations. If there is little or no reduction in price, the water circulation type has the advantage on account of greater simplicity of piping and connections, as no condensers, etc., will be needed. There will be less oil in the power house, and therefore, less fire-risk. In case of fire, if the oil has to be quickly drawn off from one transformer, it is necessary to open only one valve on a transformer using the water circulation system, while in the oil circulation system at least three valves have to be operated.

However, a material reduction in first cost in the case of large installations would probably offset the slightly greater complexity of the oil circulation system. In most plants the oil reservoir could be located above the level of the transformers, thus doing away with one of the oil pumps.

Calvert Townley (by letter): To dissipate a given amount of heat requires a given quantity of water at a given temperature-difference from that of the part to be cooled. The nearer the point at which this water can be applied to the heated material the more efficient it will be as a cooling agent. Therefore, where water is expensive or limited in supply the method of cooling by circulating it in pipes within the transformer case uses the water in its most efficient manner and has a material advantage, However, where water is plentiful and inexpensive the method of forced oil circulation permits the use of larger quantities of water, producing a much greater cooling effect.

The first instance where oil was circulated for the purpose of cooling transformers, and with which I am personally familiar occurred in the Farmington River Power Company's station, near Hartford, Connecticut, in 1896. A number of step-up transformers of 150 to 200 kw. capacity each, self-cooling, were found to be heating abnormally. As a remedy the transformer cases were tapped and a 60-ft. pipe connected thereto, which pipe, wound in coil, was immersed in the tail race. A small circulating pump, belted from a convenient shaft forced the oil through this pipe, and the result, at a negligible expense and no inconvenience, was an immediate reduction of temperature, so that the transformers worked well inside the normal margin of safety.

It will be noted that for water power installations the oil circulating plan becomes extremely simple and very inexpensive, as, where the tail race or other stream is available, no power house floor space is needed for the cooling equipment.

There is a further advantage, that, whereas in transformers

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cooled by water forced through a pipe inside the transformer cases any leak in such pipe permits the escape of water into the transformer oil, thereby endangering the life of the transformer itself, with the forced circulation of oil such leak only lets oil escape into the surrounding water, and the transformer itself is in no danger of injury.

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Discussion on Enclosed "Station Wiring," at Chicago, Ill., May 24, 1907.

(Subject to final revision for the Transactions)

C. W. Stone: I notice that Mr. Blackwell speaks of the connections being simple. I think this is a very serious matter and one that is not given the consideration it warrants. We try to make a system flexible by putting in all sorts of tie connections; then in order to save space and save cost we put in knife-switches. By putting in the knife-switches we court just what we are trying to avoid. The knife-switch may be opened by mistake. If it is opened under load by mistake there is a big arc, which may be whipped across and involve all the adjacent apparatus. Therefore, if possible, I think we should always try to keep each individual circuit entirely distinct, with no tie, and if ties are used we should use enclosed switches; that is, all switches in the form of knife-switches must be put in between barriers in order to confine the arc.

From Mr. Blackwell's paper it is quite evident the arc cannot be confined, if an arc at low voltage will jump forty feet. He also speaks of putting in barriers between the conductors. This is a very serious point with high-tension apparatus. If barriers are put between them jumping distances are shortened and therefore the barriers must be put farther apart. This makes it almost prohibitive to install bus-bars in a bus-bar compartment, because the bus-bar compartment becomes as large as the station in order to allow safe jumping distances.

One other thing in connection with the keeping apart of the high-tension conductors, and that is the point where they are brought together in order to put in potential transformers. Potential transformers are connected across between phases, therefore resulting in a tie directly across between phases through a small device. This small device must be isolated and separated in such a way that if an arc forms or an arc jumps across the terminals it will not communicate between the phase wires. This means that each lead has to go through some brick barrier or soapstone barrier or through an insulator, which is bad at very high potentials. Then the current transformer is also used, a very serious thing with high potentials. It therefore would seem good practice to eliminate all secondary devices whatever from the high-potential side, installing all instruments on the low-potential side, running directly from the transformer, say, or the switch to the line, with nothing whatever connected to it.

L. C. Marburg: What Mr. Stone has said regarding simplicity of wiring connections cannot be endorsed too strongly. There is a tendency towards introducing flexibility to such an extent that the complications necessary to obtain it form a weaker point in the system than the original arrangement, the failure of which it is intended to take care of. In other words, while

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providing for an emergency occurring, say once in three years, we may be introducing the danger of a breakdown once a month.

With regard to enclosed wiring for 60,000 volts, Mr. Stone's remarks also appeal to me. Compartments for such high voltages become too large to be practicable, and it would seem that open work if properly designed, for example the type of installation adopted at the Ontario Power Company's plant at Niagara Falls, offers as much reliability as can be obtained. If wires are separated a sufficient distance so that an arc cannot hold the installation is about as safe as it can be made. For voltages not higher than 30,000, bus-bar compartments and barriers between compartments and oil-switches have become the standard practice, at least as far as generating stations are concerned, but it would seem as if in many cases, wires were enclosed more than advisable. What is wanted are brick or concrete barriers between all bus-bars and between all switch connections, and as little brick or concrete work as possible should be introduced outside of this, so as to leave all wires and insulators visible and easily reached. For example, a bus-bar compartment may consist of one main vertical wall in the rear and a number of horizontal concrete slabs supported in front by means of small concrete columns. The bus-bars are placed in the horizontal compartments formed by these slabs, and switch connections are carried through the rear wall to switches located above or below these compartments, barriers being placed between the individual leads. This arrangement leaves all wires and insulators visible throughout, and seems superior to closed compartments and closed vertical risers between compartments and switches, as any leakage will be readily detected and as all insulators can easily be cleaned.

Instrument transformers on the high-tension side are of course undesirable, but if the station contains a high-tension bus-bar with several independent outgoing lines needing protection, they cannot be done away with entirely.

P. M. Lincoln: Mr. Blackwell summarizes his paper thus:

1. The system of connection should be as simple as will give the necessary control over the station ". I think that all electrical engineers will agree with him there.

2. " The conductors should follow the shortest and most direct line from generator to transmission line ". That, again, I think is a point where unanimous decision will be made.

Concerning the third, the vote will be by no means unanimous.

3. " Each conductor should be surrounded and separated from every other by a continuous fire-proof barrier ".

I think the vote of the large majority would be " no " rather than " yes " to that, for the reason that the principal advantage of enclosing bus-bars, wires, etc., is to prevent a destructive arc from forming between those bus-bars, etc. Now the higher the voltage of a station, the less destructive become

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the arcs. With 2000 volts I presume there is about the maximum destruction that can possibly be got; at least I have had occasion to believe that from seeing what a 2000-volt arc will do with a very large amount of power behind it. I believe thoroughly, judging from my own experience, that 2000-volt bus-bars for any very large amount of power should be enclosed, by all means; but for the same amount of power at 60,000 volts or at 40,000 volts I do not believe the same thing holds. The destructiveness of an arc is in proportion to the volume of current and goes up with some power of that volume which I do not know—the square, at least, probably much higher—and, as I said before, the higher the voltage the less the amount of current available for producing destruction. That is one very good reason for omitting these fire-proof barriers at some point as the voltage of an installation goes up.

Another obvious and very good reason for omitting those barriers is the difficulty of obtaining insulation as the voltage goes up. Any material available for barriers must be considered as dead ground on these high voltages.

For these two reasons, therefore, I believe that there will be by no means unanimous assent to this statement in Mr. Blackwell's paper.

4. "The circuits should be as far apart as possible".

This will be assented to, I believe, by the majority of engineers. This statement is in contradiction to a certain extent to his third, because introducing fire-proof barriers practically means separating the wires double the distance that would be necessary without the use of fire-proof barriers. There is no fire-proof material that can be treated as an insulator at 60,000 volts and above; that is, no fire-proof material that is available for use as barriers that can be treated as an insulator at 60,000 volts and above.

E. N. Lake: I might give an example of how this problem was worked out in a small synchronous converter sub-station designed for operation at a potential of 25,000 volts. I shall endeavor to show by a sketch the arrangement of the circuits and apparatus.

The transmission line wires were carried from the pole line to a cross-arm built into the parapet of the sub-station, thus making a design which was distinctly a part of the building structure. From this point the line wires went directly into the lightning-arrester tower. This tower was divided by a concrete floor into two stories, as shown. The back portion of the tower was further divided by vertical barriers running from the floor line of the lower story to the roof of the second story. These barriers were of brick four inches in thickness, built into both floors and the roof, thus giving the barriers a rigid lateral support. In the upper part of the structure the lightning-arresters were installed. Below the lightning-arresters the current transformers were located. Below the second floor the

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bus-bar chambers were located, which, instead of being arranged open on top were with closed top of concrete construction open below. In the lower story, or switch room were

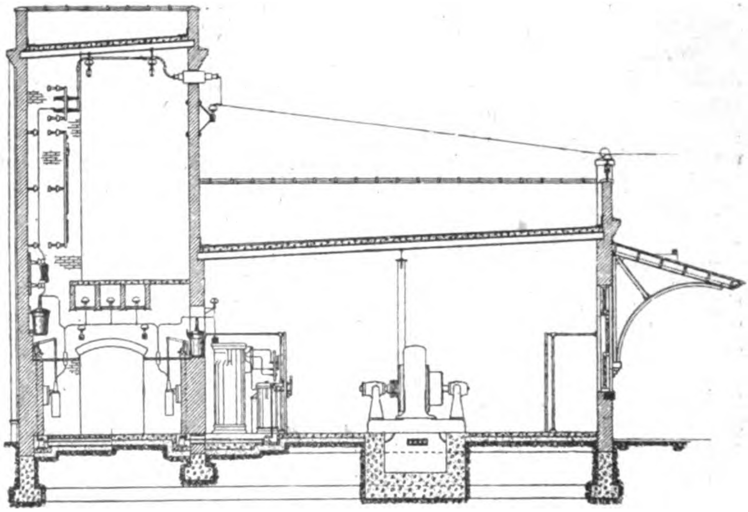

Fig. 1.

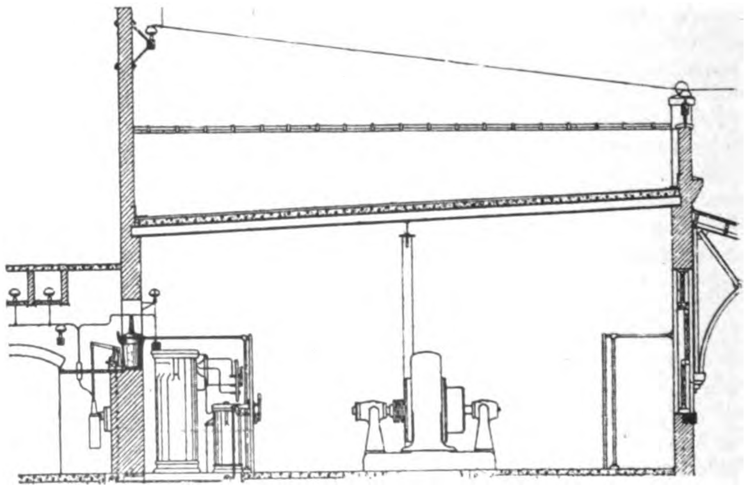

Fig. 2.

located the oil-switches. The barriers which extended from floor to roof formed the barriers between the oil-switch compartments.

The transmission line was so situated that it was convenient

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to bring the wires in directly to a lightning arrester tower located at the back of the station. The switch on one side controlled an incoming or outgoing line and the switch on the opposite side operated as an individual rotary switch. At the division wall between the switch room and the rotary room there was an arched opening in the wall for the location of the potential transformers. This construction in general accomplished the end which Mr. Blackwell has brought out in his paper, viz.: that throughout the sub-station from the point where the high-tension wires enter the disconnecting-switches on the lightning-arresters to the point where they entered the top of the step-down transformers every foot of that distance the phase wires were separated by fire-proof barriers.

L. C. Marburg: When sub-stations are taken into consideration, the main arguments advanced in favor of enclosing leads in compartments do not hold. If twenty or thirty miles of transmission lines are introduced, the individual wires of which cannot be separated by barriers, there seems little use in separating these wires so carefully in a sub-station at the end of the line. If the building is fire-proof, a momentary arc that cannot hold cannot be considered very dangerous, particularly in view of the large resistance introduced by the transmission line between the generating station and the short-circuit. Compartment work in every 200- or 300-kw. synchronous converter station would involve considerable expense.

J. D. Jamieson: It has been my fortune to see some of the extremes in high-tension work, as represented in one case of barriers carried to an excessive degree of refinement, and in another case where the potential was within 10,000 volts of the first absolutely no attempt at providing barriers between the conductors. The second case I cite bears out the remarks just made about the inadvisability of providing barriers for extremely high potential. This course might be advisable from the standpoint of normal operation, or might take care of any possible rises in potential which might be occasioned, but there is another phase of the matter with which a large central station has to deal; that is, accidental contact. With a 60,000- or 50,000-volt system of a capacity of perhaps 60,000 kw. and a reasonable number of distributing circuits, every precaution has to be taken against accidental contact, and I think if a large station were put up in the fashion mentioned, without barriers, that we would find with a working construction force of 50 to 100 men there would be quite a lot of trouble due to the absence of barriers.

With regard to the addition of knife-switches to the system, it has always been the endeavor of the company with which I am connected to do away with the knife-switches to the extent of putting disconnecting points in a circuit in enclosed partitions; that is, disconnecting-switches which are necessary in series with oil-switches, are put in the same compartment.

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On the higher potentials it is not possible to get oil-switches which are equipped with disconnecting appliances. Therefore we are forced to install knife-switches outside the oil-switch, which call for additional barriers. In some cases we go further than to provide barriers, we provide the barriers and then insulate the conductors inside the barriers. This practice has been pronounced superfluous by some, but we have had instances of the worth of such construction. There have been cases where an enormous flow of current, due to the accidental interruption of the circuit, had caused the conductors inside the barriers to be dislodged, and to rest upon the concrete shelves. In that case we found that the addition of insulation to the conductors prevented a very serious disaster. I think that barriers should be used in all cases, and further, that although there is no fire-proof material that is an absolute insulator, the effect of the short-circuit is greatly decreased even though the arc holds between the conductor and the barrier.

Fay Woodmansee: We all agree, I think, that the station wiring must be as simple as possible, and then after that the question of separating depends entirely, I believe, upon the voltage, the capacity, and also as to whether the station is a generating station or whether it is a sub-station located at the end of a line. In a sub-station located at the end of a line, I think the same as Mr. Marburg does; after a number of miles of line that has been unprotected, why in the station separate the wires from each other by barriers? In the station there is less liability for anything to get across the wires, because the wires are placed close to the ceiling. There it is almost possible for any material to get over them to cause a short-circuit and shutdown. Consequently the additional expense is not warranted, I believe, in barriers between poles of lightning-arresters, or anything which may cause an arc in its operation. But in the power house proper, where the question of keeping the potential on the bus-bars is very important and there are a number of men working in the station, I believe that the bus-bars should be separated from each other by some fire-proof barrier, as much to protect the life of the people who may be working in the building as to make the service safe. I think in a good many cases our stations are made much more complicated than they should be.

The question of running leads from bus-bars I think is a very important point to consider. It is oftentimes easier to insulate the bus-bars and run them lengthwise of the station and thus cut down to a minimum the number of feet of cable required. These cables can be run and protected in such a way that it is practically impossible to cause trouble.

P. M. Lincoln: I am thoroughly in accord with what Mr. Woodmansee has said with regard to the protection of life in the station. I think that is absolutely the first requisite that should be taken into consideration in making a switching

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layout. However, I do not believe that that element compels us to enclose each bus-bar or each wire in a fire-proof barrier. In fact, my own opinion is that the modern tendency is rather toward doing away with all buildings than putting buildings around every individual wire and piece of apparatus in a station. I think the time is coming when the bus-bars, transformers, switches, and practically everything else of that kind will be put out in the weather, and a building put around only the apparatus that it is absolutely necessary to cover, such as instruments and things of that character.

E. N. Lake: I cannot quite bring myself to agree with Mr. Woodmansee or with Mr. Linclon in regard to justifying the additional expense of barriers. In a given case, where barriers were used in a fire-proof sub-station constructed of brick concrete, and steel, the additional cost for the introduction of the barriers was probably twenty-five or may be fifty cents per kilowatt. It seems to me that such additional expense is fully justified in the matter of safeguarding life. I think that the protection of life is one of the most important things that we have to consider, it is in fact *the* most important thing to consider in designing stations for higher potentials.

P. B. Woodworth: Will Mr. Lincoln please explain how he is going to safeguard life when he has his wires out in the open with no house around them at all.

P. M. Lincoln: The space up in the air is very easy to obtain. All there is to be done is to put the station out of reach. An ordinary transmission line is not considered dangerous; it is out of reach. Exactly the same thing can be done with a sub-station. It seems to me that if it is logical to put fire-proof barriers around the individual wires in a sub-station, it is just aslogical to run those fire-proof barriers clear back to the generating station. That reduces the fire-proof barrier proposition to an absurdity.

E. N. Lake: If I were going to carry the transmission line wires from the sub-station back to the generating station in such a location that it was possible for the men in their daily work to come in contact with them, I would most certainly put the barriers all the way from the sub-station to the power house.

W. B. Jackson: Doesn't that reach the actual kernel of the matter? Namely, where it is possible for the wires to be touched by the employees in the regular performance of their duties, the wires must be protected by the fire-proof compartments or by separating walls of some kind, but as soon as the wires are carried out of that zone then let them be free. That is getting to be common practice, especially so in plants on the Pacific coast, and it seems to be the logical way to arrange high-tension wiring.

P. M. Lincoln: I think there is no disagreement on that point, that the most essential thing in putting in a sub-station must

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be to protect life, but I do not agree that putting fire-proof barriers around the wires is the only way to do that. Keep them up out of the way, where they can not be touched by the man in the regular discharge of his duties. That is one way. There are other ways, such as putting ground wires under them or around them, as Mr. Stone has suggested. I think, however, on the essentials there has been no disagreement, no very material difference of opinion among us.

Dugald C. Jackson: Your suggestion that the future sub-station will be out in the air reminds me of the stations of certain of the Western plants. They have step-down sub-stations, not converter sub-stations which require attendance, but step-down sub-stations, where the building consists practically of a light wooden framework with corrugated iron over it, and the line that passes over it drops down through the roof through suitable terminals, and the wiring is run to the transformers through ordinary fibre conduit, using the usual linen covered wire. That makes a sub-station that approaches the limit of simplicity. It is almost the equivalent of having the whole thing out of doors as perhaps it is even cheaper than to erect the structure on an elevated platform, and it also does this, which I think perhaps is likely to militate against Mr. Lincoln's proposal to put everything outdoors; it protects the transformer terminals and such switching terminals as are needed from the beating of the weather,—the sleet and rain and that kind of thing that one is bound to meet and which these terminals practically need to be protected from.

Edwin W. Olds: When you call upon me to speak upon the subjects that have been so interesting to-day, you are calling upon one who, while old in years, and in name, is very young in that part of the business. We are just putting in our first single-phase alternating current-direct current car equipments. Electrical engineering is somewhat out of my line, but is very interesting, and some of the points that have come up have appealed to me in a practical way. I am not a technical man in any sense of the word. What little knowledge I have has been pounded into me in the good old way.

You were speaking some time ago in the discussion regarding grounded conductors and the different burn-outs. I have noticed in our direct-current operation in Milwaukee that in certain sections of the city where there are a great many telephone and other wires it is very seldom that any of our cars are struck by lightning; but in other sections where the telephone and electric light wires are not so plentiful, there is trouble with our cars. From my standpoint, this is quite conclusive evidence that a grounded conductor is of a great deal of importance, for if it will protect our direct current feeders and trolley lines, why should it not protect the higher potential wires that are so much more apt to be disturbed by the lightning.

Bertrand P. Rowe (by letter): In following the development

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of systems of station wiring in connection with switchboard installations, we begin with the single generator and the primitive system of open wiring carried on porcelain knobs, which was undoubtedly borrowed from the earlier experience of the telegraph companies, As the fire hazard from poor electrical wiring became more universally recognized, insurance companies from time to time insisted on better spacings, better insulation, and absence of combustible material. The sizes of generating plants have increased, and the amounts of power that have been concentrated on single sets of conductors or bus-bars have reached such proportions that the old-time methods would not suffice for their installation. With this new set of conditions, the underwriters have not meddled. They have found that the owners of generating stations are building fire-proof plants with concrete floors, and structural iron and masonry walls, and they have no regulations to offer regarding the installation of these heavy capacities beyond what are already in vogue for those of lighter capacity. Their fire-risks in such plants are small, and they are interested more in applying their rules to the wiring of factories and dwellings where there is a fire-risk.

The designers of electrical power stations, however, have found that with increased capacities at higher voltages there exists the danger of serious damages and shutdowns, due to arcs starting between conductors, being fed from conducting gases from vaporized copper with the power of large generating units concentrated behind them.

With low-tension systems, from 125 to 250 volts, this danger did not exist, even with thousands of amperes in bus-bar capacity, fed from storage-batteries, because the voltage was too low to maintain anything but a short arc. Difficulties of this sort have been noticeable in plants of from 2000 volts and upwards, principally because 2200 volts is the lowest high-tension voltage at which large amounts of power are concentrated.

In order to prevent arcs between conductors in smaller installations, the conductors were insulated. The practice in these larger installations is to use bare copper bus-bars, and insulate them by air-spaces, inclosed in fire-proof cells. All cable connections are likewise carried in cells, as well as all apparatus liable to cause an arc.

The practice of isolating the conductors has been followed in all modern heavy capacity plants up to and including 15,000 volts. The reason for the practice will be well exemplified if one starts out to design open-link fuse-blocks. It will be seen that a fuse for 250-volt service may be constructed very easily which will carry normally 2000 or 3000 amperes, and rupture the circuit on an overload of 25% without difficulty.

Now if one starts to design 500-volt fuses, he will find that a fuse to blow at 1200 amperes is a pretty difficult problem, and with plenty of power behind it, the fuse-block will be hard to construct which will not be destroyed by the arc. The ruptur-

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ing of the established arc will be quite a difficult thing without careful study and design.

Now if one goes a step further and tries to design a 2200-volt fuse-block one will get into difficulty when the capacity gets above 300 or 400 amperes. And likewise one will find it difficult to design a successful 3300-volt fuse-block for a larger circuit than 200 amperes.

It follows, then, very readily that as the voltage rises, heavy capacity currents become more difficult to break; they maintain themselves vigorously, destroying all material which may intervene. The tendency, therefore, in all modern installations, is to suppress all high-voltage arcs by eliminating as much as possible the air-break switching devices, and by using oil-switches, and placing barriers between conductors.

What the station engineer is doing for his own protection, is heartily seconded by the Board of Fire Underwriters, who are leaving the problem alone because not so vitally interested. And the problem is undoubtedly being handled generally in a much more satisfactory way than they themselves would feel free to demand.

Some time ago, the underwriters inspected the plant of the Ontario Power Company at Niagara Falls, which has all of the conductors and switching devices in fireproof cells. The writer was much impressed by being told by these inspectors that they had only one recommendation to make regarding that entire installation, which was that a fire hydrant be placed at each corner of the building. They stated that the modern construction was ahead of anything they had seen at that time in the way of fire-proofing.

In the selection of barriers, the engineer is limited at present because the ideal commercial barrier does not exist. The common practice is to separate all conductors from each other and from grounds, using such distances that concrete or brick barriers may be used with safety. At high voltages, these substances must be considered as grounds, since they absorb moisture, and this makes necessary much wider spacings than if the barriers were of insulating material. Soapstone, while a little better than these, is still an absorbent material, unless impregnated. Porcelain is too dear, and glass will not stand an arc. Asbestos lumber and transite make admirable fire-proof barriers but are poor insulators.

Probably the nearest perfect barrier would be an impregnated material like soapstone, and this is of course expensive. No cheap insulating barrier being known, the common practice is to support all conductors on suitable insulators and rely on the grounded barriers for fire-proofing. The best practice assumes that all insulated cables are subject to deterioration, and unless they are protected by lead coverings with suitable end-bells, they are invariably as well supported on insulators as a bare cable should be. This insures permanency.

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For installations of voltages above 15,000, the cellular construction is not so prevalent. But the subject for high-tension wiring for these voltages deserves great attention, because, as stated by Mr. Blackwell, this part of the installation usually gets scant attention when the building is designed. The very best modern practice is to lay out this system of wiring in advance and design the building to suit.

The writer does not agree with Mr. Blackwell that the use of barriers and fire-proofing for very high tension wiring is at present more important than for those whose potential is from 2000 to 15,000 volts, for the reason that at the very high voltages now employed the sizes of conductors are very small. They will usually burn away instead of maintaining a fierce arc, such as might be expected if heavy masses of copper are short-circuited. The practice of most station designers seems to sustain this view of the case.

One of the reasons why the use of barriers and cells for conductors has not been more extensively carried to higher voltages is because the generating voltages now deemed practical are all below 16,000 volts. Whenever the manufacturers are ready to put commercial generators on the market to generate current at 20,000 volts, this construction will be seen adopted universally for that voltage where heavy capacities are used. There are even now some cases where large quantities of power are to be distributed at 33,000 and 45,000 volts, and the cellular construction is advisable because of the heavy capacities that are carried on the bus-bars.

In the writer's opinion the use of the barriers and cells, such as are common with the lower voltages, are an unnecessary refinement in a majority of cases. In almost every plant operating at pressures of 45,000 volts and upward, the potential of the transmission system is raised to such a value that, with a given line-loss, the size of conductor can be made as small as mechanical considerations will warrant, to save expense in the transmission line. So long as this practice obtains, and unless large amounts of power are concentrated on high-tension bus-bars by banking the step-up transformers, there will seldom be large masses of copper in the high-tension system to maintain an arc. In fact the condition where heavy conductors may be required on the high-tension system of 45,000 volts or more, can be, and usually is avoided, by feeding separate banks of transformers into their own transmission lines, with a relay bus-bar of small capacity to enable circuits to be transferred from one bank of transformers to another in case of trouble.

In a modern power station, using oil circuit-breakers, if the idea of barriers between all high-tension conductors, irrespective of capacity, were logically carried out, it would be more necessary to require these barriers between the wires on the transmission line where the conditions of atmosphere and moisture are more conductive to short-circuits, than to require them in a properly wired power station where they are enclosed and dry, and as well

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separated as they are on the poles. Where air-break switching devices are used, however, fire-proof barriers are certainly necessary if there are conductors near enough to the arc to cause any apprehension.

Another argument against the use of barriers between very high tension conductors in power stations is the increased size of station often required if the idea is carried out properly, owing to our inability to obtain a satisfactory insulating barrier. As stated previously, all known barriers, except those of glass or porcelain must be considered as grounds for high-voltage circuits, and glass and porcelain barriers are not practicable because of brittleness and expense. Therefore, we are forced to use grounded barriers, and the introduction of these barriers between the high-tension conductors in a station compels us to space our conductors much farther apart than they are for the transmission line, to provide sufficient insulation distance. It will be found that to install these barriers properly, a larger amount of room and expensive construction will be required that is usually unwarranted.

The most practical way to handle the problem is to confine all apparatus which is liable to arc, and separate the conductors by suitable air-spaces, using insulated conductors for the sake of safety. A time may come when reliable insulating material may be obtained in the form of fire-proof tubes through which these conductors may be carried, and which will be sufficient insulation to allow closer spacing of conductors. In such a case the saving in space in a power station will be justification for using them.

The writer believes thoroughly in providing an insulating covering for all high-tension conductors carried in air in the interior of a power station as a safeguard against accidents due to accidental contacts. While it is preposterous to think that cables carrying 60,000 to 88,000 volts may be insulated for safe handling, yet the writer believes that they should be as well insulated as possible to prevent workmen from getting killed by contact through poles or other implements.

In addition to this the wires should be marked with danger signals and warnings to remind the unwary. These precautions may save loss of life and bills of damages which are usually awarded against power companies who are found guilty of carrying their deadly current on bare conductors where workmen may be near enough to get shocked.

It may be possible to insulate the conductors with some of the special tubing now on the market, with some form of impregnated oiled muslin next to the cable so that there is scarcely any danger to the cables, by preventing possible arcs. The writer believes that the best and most conservative practice in most cases will be to try to provide such arc insulation as this, and then support the entire insulated cable on insulators with good free air spacings between all adjacent conductors and to ground.

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Stephen Q. Hayes (by letter): The writer agrees with three of the principles enumerated, but does not believe that in stations where voltages of 33,000 and upward are obtained by means of step-up transformers "each conductor should be surrounded and separated from every other by a continuous fireproof barrier", and for the following reasons:

First, the violence of an arc and the destructive effect of a short circuit seem to depend more on the amount of current than power available, or for the same amount of power would diminish with increase in voltage.

Secondly, the short-circuit current available on the secondary side of a transformer is less than that which would be supplied by a generator wound for the same voltage and connected directly to the bus-bars. The use of the transformers introduces a cushioning effect.

Thirdly, as the fire-proof barriers offer a more or less perfect ground for high-voltage circuits, the striking distance from wire to ground has to be greatly reduced over what could be obtained with open wiring in the same space.

Fourthly, the use of enclosed bus-bars and wiring ordinarily necessitates several floors or galleries and a more expensive building and more costly structures than the open wiring.

Fifthly, it is more difficult to inspect and repair bus-bars, wiring, disconnecting-switches, lightning-arresters, etc., that are boxed in masonry compartment and only visible and accessible by the removal of doors than if everything was in plain sight. Incipient trouble will be noticed far sooner with open wiring than with enclosed and inspection will be more frequent and thorough if the station attendant in a few minutes walk can see everything, than if he had to remove several hundred doors and visit two or three floors to examine the condition of the apparatus.

As Mr. Blackwell refers particularly to the Toronto & Niagara Power Company's transformer house at Toronto as a typical example of the enclosed wiring and bus-bars, it might be stated that at the time of a recent visit to that station in February, the static discharge apparently from the 60,000-volt wiring and bus-bars could be heard all over the building. This trouble may have been remedied since that time, but is one far more likely to be met with in a system of enclosed wiring than in a system of open wiring such as that of the Ontario Power Company's Plant at Niagara Falls.

C. W. Hutton (by letter): Enclosed station for the higher potentials has not, as stated by the author, been given the attention which it would appear its importance demands. Cable insulation for potentials of 50,000 volts and upwards seems out of the question and the only alternative seems to be the use of long bus-bar ducts with the conductors mounted on suitable insulating supports, (the ordinary line insulator being the most common practice). The arrangement of the apparatus which would seem most simple and satisfactory would be to set the transformers in a straight line and in groups. A moderately

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heavy brick wall should be built immediately back of the transformers with openings suitably arranged for the passage of the high potential wires from the transformers, which should be set with their high potential sides next to the wall. Suitable open air disconnecting switches should be interposed between the transformers and the openings in the wall and be mounted upon the brick wall immediately above the transformers. Three bus-bar ducts (considering that three phase working is to be used), preferably of tiling on account of its many desirable features, each having a section of approximately 2 ft. 4 in. by 2 ft. 6 in. high should be arranged one above the other immediately back of the brick wall, the bottom of the lower duct being approximately level with the tops of the transformers.

Sectional bus-bars and line oil-switches should be arranged in tile compartments immediately back of the bus-bar ducts, the bottom of the compartments being on a level with the bottom of the lower bus-bar duct. Suitable hand-operated oil-switches for plants of from 10,000 to 15,000 kilowatts can now be made up in three-pole units at a cost of about $175.00, including the remote-control apparatus, so that the liberal use of oil-switches is not prohibitive on account of expense.

One of these three-pole units can be very conveniently installed in a space of 5 by 5 by 10 ft. long. From the oil-switches used for the individual line circuits, the lines pass through suitable wall openings to the outdoor disconnecting switches mounted on poles immediately adjoining the building, thence to the transmission lines. Remembering that all oil-switches have open-air disconnecting switches on both sides, it will be seen that it is never necessary to open the air-switches under load. Practice has shown the above arrangement to work out very simply in construction and highly effective in operation.

The low-potential station wiring at any voltage from 15,000 down has been so well standardized that time will not be taken to discuss it.

Wm. McClellan (by letter): There is little doubt that the enclosed wiring is much more desirable in power stations and sub-stations when the voltage is less than say 20,000. Above this voltage, engineers would do well to favor conditions which will permit of open wiring as much as possible. It is a note-worthy fact that, for the same power, as the voltage increases, the arc, although capable of jumping over longer distances, becomes in itself less destructive. It may also be noted that about the only time an arc can start in a properly designed installation is where open switching is done. So far as bus-bars, tap connections, and apparatus terminals are concerned, there is no danger whatever in open wiring. The remedy then is to make use of oil switches. It is usually found that for very high voltages the amount of space required and the cost of complete installation would be far greater for the enclosed wiring than for the ordinary open type. It is quite apparent that the trend of design for very high voltage sub-stations is towards an inclosure

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as small as possible. The writer's conception of the future very high voltage sub-station, or step up portion of a power house installation, is a small switching compartment enclosing the control switches and meters, with transformers, and remote controlled oil switch all out of doors. Under these circumstances the lightning arrester is about the only place at which it would be possible for an arc to start. As this will probably be out of doors anyway, it does not affect the general question. Should we be so fortunate as to get all that the electrolytic arrester seems to promise, we should have no trouble here.

L. A. Herdt (by letter): Large hydroelectric plants of recent design, operating under high voltages and developing large amounts of power, show so much variety in the arrangement of the electrical apparatus as to suggest wide differences of opinion among the designing engineers as to what is considered necessary and advisable to guard against the spread of arcs and to protect the apparatus from trouble if it exists in one part of the plant.

In some cases the isolation of the high-tension apparatus and conductors is carried out in such a way that each conductor is surrounded and separated from every other by combustible walls and barriers. Transformers are placed in pits and isolated from one another by heavy masonry fire walls. On the other hand, in one of the largest hydroelectric plants of this country, the high-tension bus-bars and disconnecting-switches are placed in an open room without any intervening sections or barriers; the transformers are walled in, but in groups of three.

In another installation of considerable size the transformers will be found all placed together in one room, the high-tension wiring is open without barriers of any kind; considerable distance is allowed between the conductors and this has, so far, afforded sufficient protection.

The writer, however, agrees with Mr. Blackwell that high-tension apparatus and conductors require to be guarded against the spread of arcs, and should be protected from fire spreading from adjoining apparatus or from external sources. This protection is best secured by fire-proof barriers, but the extent of this protection and the expenditure thus incurred should bear some relation to the amount of power generated and the revenue to be derived from the sale of the power. The writer is of opinion that when there exists a number of high-tension transmission lines carrying large amounts of power, each transmission line with its high-tension switches, bus-bars, lightning-arresters, and transformers forming one unit, should be separated altogether by fire walls and the like from the apparatus belonging to another similar set. The high-tension bus-bars common to all the different units should be constructed with great care, and whether placed in continuous fire-proof barriers or not they should be provided with disconnecting- and tie-switches, so that each unit could be operated as a separate plant or could be coupled with the others when found advisable.

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Discussion on "Power-Factor, Alternating-Current Inductive Capacity, Chemical and Other Tests of Rubber-Covered Wires of Different Manufacturers," at Niagara Falls, June 25, 1907.

(Subject to final revision for the Transactions.)

Henry W. Fisher: In presenting this paper to the Institute I wish it to be clearly understood that no attempt has been made to say anything or do anything that would be discourteous to the manufacturers of rubber-covered wire. The main object of the paper is to compare a large variety of rubber-covered wires, especially with reference to power-factor and dielectric loss. So far as I know these tests have not been applied commercially to any extent here.

A careful examination of the results given in the paper will show that power-factor tests are valuable in helping to determine the quality of rubber-covered wires, but that they cannot be relied upon to indicate the amount of fine Para. All the tests given are essential, especially the chemical, voltage, and insulation resistance tests.

Chas. P. Steinmetz: This paper is interesting in giving what may lead to an advance in our method of judging cables. It proposes to investigate the character of cables by measuring the energy loss in the cable as represented by the power-factor. The energy loss in the cable appears to me a very important quantity. However, I do not believe it would be safe to judge cables merely by this energy loss. What is important in a cable or any condenser is 1: the disrupted strength; that is, that the cable stands the operating voltage with a sufficiently high limit of safety, and 2: the deterioration, that the cable does not deteriorate at the operating voltage within a reasonable time. Deterioration is the effect of energy, consumed in the dielectric of the cable, Therefore, if one could imagine a cable which has no energy loss whatever in the dielectric or zero power-factor, such cable would not deteriorate. This shows the importance of the energy loss in the cable. However, the deterioration is not necessarily, and probably in general is not proportional to this energy loss.

We do not know much, to tell the truth, of this energy loss in the dielectric in the alternating field. We suppose there is some kind of a dielectric molecular friction similar to the molecular magnetic friction of iron; that is, a conversion of electric energy into heat during cyclic changes of static stress. This dielectric hysteresis is harmless, regarding deterioration, because it is a conversion of the energy into heat and merely raises the temperature of the cable slightly, just as the current existing in a conductor raises it, and if we keep the temperature of the cable sufficiently low, no deterioration will take place owing to this heat. So the production of this additional heat by dielectric hysteresis, must be taken in consideration in designing a cable system.

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There is, however, a phenomenon, no analogy of which exists in the magnetic field; that is, a conversion of energy not directly into heat, but into chemical action, and that probably is what leads to the deterioration, the destruction of the dielectric. It is a chemical action exerted upon the dielectric proper, or upon gases included in the dielectric, either absorbed or as air bubbles, etc. If we could separate the energy converted into chemical action from the energy converted directly into heat, we could draw conclusions, the former may give us a clue to the probable life of the cable or condenser. But even then it may not give a direct estimate of the life, because the distribution of the destructive energy is all important. We may have cases in which the energy converted into chemical action, that is destructive energy, is moderately high but uniformly distributed over the whole cable, and the cable so has a good life, while in other cable in which much less energy is acting destructively, may rapidly go to pieces, because the total chemical action, although less is concentrated in a few spots, some air bubbles there weaken the dielectric, rapid oxidation of the rubber etc., takes place, and so disruption. That latter feature is well known to any one who has attempted to build electrostatic condensers for very high voltage. There the chemical energy is localized at some few spots where air bubbles have remained in the dielectric, and destroy it.

While we do not yet know much concerning the laws of energy loss in dielectrics, we know that a part of it, the dielectric hysteresis proper, probably does not vary proportionately to the square of the voltage, and so does not give a constant power-factor independent of the voltage, but a power-factor which probably decreases with increase of voltage, while from other observations and theoretical reasons it appears probable that the chemical destructive action at higher voltages increases more rapidly than the square of the voltage; that is, the power-factor increases with increasing voltage, and it appears to me, any conclusion which could be drawn from measurement of the power-factor of the cable could be drawn only if the power-factor is measured at the operating voltage, at which the cable is to be run, and that is the main objection I have to the paper, although in general I agree with the trend of it. I think that power-factor and energy measurement are made at 75 volts, if I am not mistaken. I believe they should be made at the voltage at which the cable is supposed to operate.

I wish to call attention to the statement that the condenser with the internal energy loss can be represented by a perfect condenser in series with a non-inductive resistance. I do not think that is quite correct. I think an imperfect condenser can be represented by a perfect condenser, shunted by a high resistance. If we consider the extreme case, where there is a very high loss, a series resistance would mean the wattless component of voltage is reduced thereby, which is hardly probable. In the

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present case it makes no difference because the non-inductive resistance is very small, compared with the remaining wattless effect, but where there is a very considerable energy loss, I think the safer way is to put it that the imperfect condenser is represented by a perfect condenser shunted by a non-inductive conductance.

The paper certainly refers to a feature that has not always been given proper attention; that is, the importance of the energy loss in the cable, not for the sake of the efficiency of the plant, but for the sake of its possible effect on the life of the cable. One great difficulty in this matter is the method of measuring the loss, which the paper says is difficult and complicated, and not very easy to do under usual factory conditions.

E. W. Stevenson: In the early part of the paper Mr. Fisher mentions something about the change of dielectric with the temperature. I would ask him if it is an admitted fact that the smaller change of dielectric resistance due to temperature shows a higher percentage of pure para? The reason I ask this is because recently I read a specification that called for a very small change of dielectric resistance per degree of increase or decrease in temperature. That is the first time such a requirement has been called for. There has been considerable argument upon it, whether it is so or not.

Henry W. Fisher: The temperature coefficients vary with the ingredients mixed with the rubber, and probably also with the steam temperature and pressure and time of vulcanization. The coefficients are generally less the higher the percentage of fine Para rubber. The coefficients are not uniform throughout a considerable difference of temperature. In some cases the curves representing the coefficients in terms of temperature are of double curvature and sometimes single curvature. I presented curves showing these peculiarities at the Asheville meeting two years ago.

Henry G. Stott: This is a subject in which I take a great deal of interest. It seems to me that the paper starts in from the wrong point of view. A number of different types of wire are taken and analyzed as closely as possible, and then the results of various tests are given to show just how the various characteristics varied with a change in composition. I think we could get a great deal more information if the manufacturers would start out with a definite composition and increase just one ingredient at a time, and follow that up so that we could get a complete curve of variation due to various percentages of that ingredient and so on, following through with the percentage of para, various extracts, mineral matter, etc. But if we could start on a definite basis and build up first one characteristic and then another, I think we would arrive at something very definite upon which specifications could be based.

The paper on specifications for rubber-covered wires by Mr. Langan, read a little over a year ago, assumed to give such speci-

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fications. On trying to carry out the specifications enumerated, stretching tests and others, I found that the same results could be duplicated by entirely different compounds, African rubbers, mixtures of various sorts, reclaimed rubber could be made to give practically the same characteristics as 30 per cent. or 40 per cent. para rubber, and based on that I published a series of tests made on different types of compound to show how impossible it was to depend on anything at the present time except on the manufacturer's word, as to what the wire contained. Chemists all agree that it is extremely difficult, if not impossible, in any analysis to say exactly what the constitutents are in any given rubber compound.

Henry W. Fisher: I am interested in Dr. Steinmetz's remarks and fully agree with him that tests of this sort should be conducted at higher voltages. However, at the time these tests were made the apparatus available was designed for low voltages, and the wires tested were those used generally on 100-volt lines.

It is my intention, however, soon to use higher voltages, in connection with which special apparatus like condensers, transformers, etc., will have to be designed. Probably the apparatus most difficult to obtain would be a good mica condenser of low power-factor and high capacity to operate continuously at from 6,000 to 10,000 volts.

Answering Dr. Steinmetz's criticism relative to the method of connecting the resistance in the standard condenser circuit— in getting the power-factor it is immaterial whether the resistance is in multiple or series, so long as the right formula for each case is employed. This formula for series connection was obtained from Dr. Rosa, of the Bureau of Standards and undoubtedly is correct. The resistance is used in series with the standard condenser to make the phases of the currents in the two branches of the bridge the same.

I will ask Dr. Steinmetz if he has treated this problem analytically to see if the series resistance method is incorrect, or whether he reasons from analogy that the resistance should be in multiple with the condenser?

Chas. P. Steinmetz: In the magnetic circuit, the resistance which represents the equivalent of the loss of power in the magnetic cycle, is in shunt to the circuit. In the electrostatic field we do not know enough to say whether there is a series component, but the assumption is justified that there is an electrostatic hysteresis similar to the magnetic hysteresis, and in this case, the wattless component and the energy component should be shunted to each other, as in the case of the magnetic circuit.

I may say that as the formula was worked out by Prof. Rosa, it was undoubtedly worked out for a case like this, where the energy quantity is very small, and where, therefore, in the first approximation, it is immaterial whether you put the resistance in series or in shunt. The question would become of importance when the energy component is considerable compared with the wattless component.

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E. W. Stevenson (by letter): At the end of Mr. Fisher's paper he lays particular stress on the low breakdown voltage of the white core samples. This is a very interesting fact, especially as it comes from such an authority as Mr. Fisher. I certainly admire his courage in making the statement. I have always been strongly of the opinion that white core is nothing more than a fad. Of course it is generally understood that the white core does not contain sulphur, and therefore is used for the purpose of preventing the sulphur of vulcanization attacking the copper of the conductor. But of course all copper in rubber-covered wire is tinned, and this tinning, as everybody knows, is merely for the purpose of preventing this action, therefore if the tinning is done properly what is the use of complicating the covering process by putting on a white core?

The British navy requirements call for a pure para next to the conductor, a second covering, called a filler, in which there is no sulphur, and a third covering of vulcanized rubber on the outside, thus making three separate covers. This forces the manufacturer to use strip method of covering which, as many of us know, is not the best for all cases.

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Discussion on "Interaction of Synchronous Machines", at Niagara Falls, N. Y., June 25, 1907.

(Subject to final revision for the Transactions.)

E. J. Berg: Any paper which tells in a simple way how to calculate the characteristics of two machines in parallel is valuable, especially when the equations or diagrams give the synchronizing power. From this we can determine the stability and the natural period of the machine, in other words we can predict something about its hunting tendencies. I doubt, however, if this paper will give this information and I ask Professor Brooks for some explanations. Professor Brooks uses the reactance and the resistance in the total circuit. It must be remembered that machines having the same synchronous impedance, which means substantially the same synchronous reactance, have widely different characteristics. For instance, a machine of definite pole construction and a given synchronous impedance may have an angular displacement of the armature at full load of 15 degrees, whereas another machine of the round rotor type having substantially uniform magnetic reluctance may have 30 degrees displacement with the same impedance. It is obvious therefore, that any calculations based upon the reactance are of little value in determining its characteristics.

I hope that I am mistaken in thus interpreting the paper and that Professor Brooks can explain that he has taken into consideration not only the true reactance of the armature, but the armature reaction, that is the demagnetizing or magnetizing effect of the armature current on the field.

Chas. P. Steinmetz: I agree with Mr. Berg that these diagrams, and also the original diagram of mine that has been referred to, applied not to existing but to ideal machines. To illustrate; with change of field excitation the current rises—on one side leading, on the other side lagging; but they are not suitable to predetermine exact values, because they apply to a machine in which the reactance is constant, the armature reaction constant, the magnetic inductance, as brought out by Mr. Berg, constant in all directions. Such machines do not exist. Try experimentally to reproduce the diagrams I gave in my paper many years ago and you find near the non-inductive load, near the minimum point, you get about the same shape, but toward much lower or higher excitation you get values which may not be exactly the same as calculated.

For higher values of excitation, the experimental curve more and more deviates from the calculated, due to magnetic saturation. For low values of excitation, the curve should bend back before reaching the zero line of voltage. Instead of this, the experimental curve can sometimes be made to cross the zero line. If at constant impressed voltage, you gradually lower the field excitation from that corresponding minimum current down to zero, and then reverse the field, the machine keeps in step and you may bring up the field in opposite direction, until you

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have a very high reversed field excitation, and still the machine runs in the same step, with the armature reaction producing the field against the opposing magnetomotive force of the field circuit, until suddenly the machine slips one pole back and with the same field excitation, everything remaining the same, the current drops down to the value which corresponds to the positive value of excitation. Now, that no diagram shows because it is the effect of the asymmetrical magnetic structure, that is the magnetic flux is not in line with the resultant magnetomotive force, but differs therefrom by a certain angle being closer to the center line of the field pole, and this feature throws any simple calculation out, and requires a much more complicated system of diagrams in which you have to consider the two separate components of magnetic inductance, and of armature reaction. The reactance is not a constant, but a function of the position, has different values in two directions at right angles to each other and the magnetic reluctance of the circuit also has two values. You must divide the system into two components, which can be done, but makes it a little more complicated.

Comfort A. Adams (by letter): Without wishing to subtract in any way from the credit due Professor Brooks for his very interesting paper on "The Interaction of Synchronous Machines", it is only fair to state that the principle diagrams there described were published by Professor Blondel in 1895 in "L'Industrie Electrique", and later in his book on "Synchronous Motors". The writer has used the Blondel diagram for the last twelve years in his classes and has found it a great aid in making clear the operation of synchronous machinery. He therefore appreciates most highly the interesting additions to this diagram made by Professor Brooks.

The quantitative relations between the armature resistance and reactance shown in this paper lead one to assume that the *leakage reactance* was chosen in place of the *synchronous reactance*, which should have been employed.

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Discussion on "Fractional Pitch Windings for Induction Motors", and "Zigzag Leakage of Induction Motors", at Niagara Falls, N. Y., June 28, 1907.

(Subject to final revision for the Transactions.)

J. C. Lincoln: Have experiments been made to determine the relative importance of the three kinds of leakage found in induction motors?

1. The leakage across the slots.
2. The leakage across the gap, or so-called zigzag leakage.
3. Leakage in the end-connections of the stator winding.

Have experiments been made to determine the relative importance at full-load of these three sorts of leakages with reference to the main or useful flux?

Chas. P. Steinmetz: I want to call attention to one point that Professor Adams did not touch on, and that is with fractional pitch windings the extra insulation necessary plays an important factor in the design of both the motor and the alternating-current generator. That is, if we assume a Y-connected machine, three-phase, and use a fractional pitch we have increased insulation necessary on the end-windings where the opposite phases come together in the same slots. This has quite an effect on the design. I think that the vast majority of the motors we are building to-day of the induction type are built with fractional pitch windings as are also most of the alternators.

B. T. McCormick: I ask whether the claim for extra insulation is on the end-connectors or in the slots?

Chas. P. Steinmetz: The insulation is progressive; that is, if we start from the neutral point as we go out from the neutral point the extra insulation is necessary, because we have the full potential between phases instead of the potential from the winding of the neutral point.

Comfort A. Adams: Referring to the effect of fractional pitch upon the exciting current—I should like to point out that not only is the electromotive force induced in a fractional pitch winding by a given flux, less than that of a full-pitch winding, but the magnetomotive force and the flux produced by a given current with fractional pitch is less than that for full pitch. In other words, fractional pitch introduces differential action both in the electromotive force and in the magnetomotive force generation. The two differential factors are fully treated in my paper.

It was stated by one of the speakers that if the magnetizing current increased in the same proportion as the reactance decreased, there would be no resulting gain in power-factor. That there is in some cases a very decided gain will be apparent when it is remembered that these two elements vary approximately in reciprocal relation. Take, for example, a motor in which the exciting current is 14% of the load current and the reactance electromotive force 30% of the induced electromotive force; assume that the pitch of the winding is reduced in such a way

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that the exciting current is increased one- and a-half times its original value, namely to 21%, then the reactance will be reduced to approximately two thirds of its original value, or about 20%, giving thus a total quadrature component of 41% in place of 44% for the full pitch winding, which means a material improvement in the power-factor, to say nothing of the increase in starting torque and break-down torque. Of course an appropriate reduction in the number of primary conductors would have approximately this same effect.

The extra insulation required by fractional-pitch windings would hardly be an item of any importance in induction motors of ordinary voltage, but might easily take on considerable proportions in high-voltage alternators.

A. S. McAllister: The problem of determining the exciting current or the "wattless volt-amperes" is rendered very simple when the solution is based on the fact that any energy that is magnetically stored in the field during any part of the cycle must be restored during the next part of the cycle, in any machine which has an alternating flux. Of course, the relation just stated does not hold in the case of the synchronous motor, where magnetic energy is initially stored in the exciting field but not given out during any part of the cycle. If in the induction motor, we find the volume of the main magnetic path and divide it by the permeability, and find the volume of the teeth and divide that by the permeability, and find also the volume of the air gap and divide that by the permeability, (which happens to be one) and multiply each of these values by the square of the flux throughout the respective path, we can determine the value of the magnetic energy stored in each of the paths; this same magnetic energy is given out through each cycle. Therefore, the "quadrature watts" or the "wattless volt-amperes", can be calculated just as one calculates the core loss watts in a motor, or in any other apparatus in which the flux is alternating. This fact was mentioned during the Milwaukee meeting at which time an equation was given for representing the actual value of the wattless volt-amperes.

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DISCUSSION ON "TRACK-CIRCUIT SIGNALING ON ELECTRIFIED ROADS", AT NIAGARA FALLS, N. Y., JUNE 28, 1907.

(Subject to final revision for the Transactions.)

Charles F. Scott: This paper is quite special in its scope and is valuable for the information it gives, but is not apt to be fruitful of general discussion. I have been interested to note during the reading of the paper, and also in my observation during the last few years of this signal development, of the general course of that development and the effect of the electrification of railways on signal work. At first on the ordinary steam road, the only electricity used in connection with the track system was the small amount employed in connection with the signals. The use of the track, however, for carrying direct current for railway motors has caused some voltages to be introduced which begin to affect the signal circuit and they have to be taken care of in ways which when they are worked out and explained seem simple and adequate, but did not seem so simple when the difficulties first arose. The introduction of single-phase alternating current and the use of the rails for conducting this current again introduces a new kind of disturbance in the signal system. It is interesting to note how the signal work has followed these various intrusions of greater currents. One rail was set aside for signal work, and later on the signal system adapted itself to the condition existing when both rails were used for propulsion current. The signal engineer follows the example of the railway engineer and gets into alternating current; if the alternating current in the railway is bad for his work he cures the evil by adopting alternating current himself. He solves the frequency question by going to a high frequency instead of a low one. This also illustrates the amount of electrical engineering which can be applied to what most of us who have not come in contact with this work at all have probably considered a very simple sort of thing, but the grade of engineering work and the knowledge and ingenuity required in devising these systems, with the remarkable reliability and excellent way in which they perform their work, is something to elicit our admiration. There is still another source from which other currents may come and affect the signals, which I understand has been characteristic of one installation, and that is when the tracks were bonded together for the operation of the railway these track connections formed an inviting path for currents from adjacent railways which were strolling through the earth, hunting convenient paths by which to get home, and these currents got into the tracks, and the signal apparatus producing some unexpected combinations of signals. This illustrates again the interference between different kinds of currents and the need of the signal engineer to be alert for their avoidance.

Henry G. Stott: I think we ought to be congratulated on the presentation of a paper of this character. It is perhaps significant of the very small general knowledge on the subject of

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the signaling system which we have, that so few people are ready to discuss it. I am connected with a railroad which is using the type of signaling described in Mr. Howard's paper, and I am perfectly free to admit that I know very little about it, We have a signal engineer, but his work is so specialized that it is an entire department by itself. If we all knew what signaling engineering was and the mass of details with which the signal engineer must contend and the wonderful ingenuity which he displays in arranging them, I think we would put the signal engineers at the very top of the class instead of the bottom.

In the first operation of the signaling system on the Subway in New York City considerable difficulty was encountered, due to the fact that the source of supply of the current was one which had variable electromotive force. The 60-cycle current was generated by a generator coupled to a direct-current motor which was operated from the ordinary third-rail current and subject, therefore, to very wide fluctuations of voltage. That reacted, of course, to keep the tongues of the relays on the signal system almost in continuous vibration, thereby reducing the life, and in some cases with very wide changes, resulting in failures in the signal apparatus itself. We changed that over so that the current is now supplied directly from 60-cycle turbines and the regulation on that is one per cent. Since that time the failures of signals to operate have diminished so that they practically do not exist. I forget what the record is, perhaps Mr. Howard has stated it, but I believe it is about one failure of the signal to operate in three or four million.

It seems to me that this development of the complete block system has got to come to all railroads. Until such is the case the appalling accidents which have taken place on many of our main lines during the past year will continue, because in the operation of power plants, and in the operation generally of all important apparatus, we find now that the apparatus itself has improved to such a point that the failures are not of the apparatus but of the men who operate them. A man may go along perfectly for years, doing the same thing every day and then he fails absolutely. For example, in the power plants with which I am connected, in three years we have had only one shutdown, and that was caused the other day by the gross blunder of a man who has done the thing perfectly hundreds of times, failing to do what he should have done. He could not explain it and no one else could explain it. The more we can eliminate the human element from our signal system the more perfect they will become.

Charles A. Perkins: It seems to me that this paper calls our attention to the desirability of extending the block system much beyond the range of signals; it is desirable not only that the signals should be given, but also that the obeying of the signal should be beyond the option of the engineer or motorman who is operating the train. I have been in an accident caused by the

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engineer on a following train running by a danger signal. In the multiplication of automatic schemes for safety, such a scheme should be included in the block and signal system. I should like to hear from Mr. Stott as to how far this has been accomplished.

Henry G. Stott: On the Subway system this feature is absolutely automatic. The man cannot run past the signal. If he does the brakes are automatically set and the current is cut off. It is absolutely impossible for him to run by the signal without its being known. They may do it once, but they are not likely to repeat the offence, because they have got to get down and go under the car and reset the air-brake valves under the car before they can start the car again. This means when they get to the end of the line, they have to make an explanation why they ran by the block, and that means they are laid off for a week.

L. F. Howard: I shall make a few comments on the matter of the automatic stop. It is used on the Boston elevated, and I believe there are a few automatic stops on the Chicago elevated system. The matter is also being agitated on some other roads. On surface roads it is more difficult to apply, on account of weather conditions, when it is down on the ground. A number of years ago it was suggested that an arm should extend from the signal mast, when the signal was at danger, this arm to be so arranged as to engage with a glass tube or stop cock on top of the engine cab. The tube or cock being connected with the train pipe of the braking system, the breaking of the glass tube or opening of the cock, in case the engineman ran by a "stop" signal, would set his brakes.

There are, however, quite a number of points in connection with the use of train stops or surface roads as yet undecided, and the present general feeling amongst the officers of such railroads is to adhere to present practice and exercise closer checks on their employees.

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DISCUSSION ON "REGENERATION OF POWER WITH SINGLE-PHASE ELECTRIC RAILWAY MOTORS", AT NIAGARA FALLS, N. Y., JUNE 28, 1907.

(Subject to final revision for the Transactions.)

W. I. Slichter: The possibility of regenerating power with single-phase motors is one of the valuable features of the single-phase system and one which will be of great assistance in bringing the motor into the field of heavy railway work. The possibility of regenerating at various speeds is well illustrated in Mr. Cooper's paper, but it is interesting to note that there are two points in the system at which the speed can be varied; first, by changing the tap on the transformer from which the exciting motor obtains its excitation; secondly, by changing the tap on

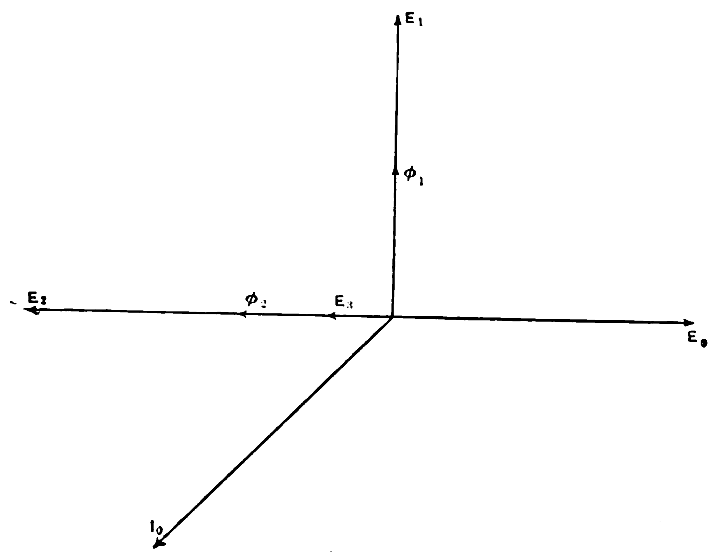

Fig. 1.

the transformer to which the generating motors are connected. These two actions may be independent, giving twice as many steps as there are taps. With this arrangement a very large number of taps on the transformer is not necessary.

With regard to the phase of the current which is returned to the line, there is liable to be a low power-factor, due to the inductance in the motor, the line, and the steel rails. This can be improved by a compounding effect in the motor which is acting as a generator, as shown in Figs. 1 and 2.

E_0 represents the electromotive force of the line, or at the secondary of the transformer, which is impressed on the field winding of the motor that is acting as an exciter. The flux which is set up in these fields will be displaced approximately

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90° behind E_0, as at ϕ_1. The armature of the motor used as an exciter revolves in this flux and produces a voltage in phase with ϕ_1, as shown by E_1.

This voltage being impressed on the separately excited fields of the power motors, produces a flux in their fields displaced 90° behind E_1, as shown by ϕ_2.

The electromotive force generated by these armatures is in phase with ϕ_2 as E_2, which is nearly in opposition to the line voltage E_0, giving a resultant electromotive force E_3.

This resultant forces the current I_0 through the windings of the motor and transformer, in which there is a considerable amount of inductance, and the current will lag behind E_3 an amount depending upon the inductance of these circuits.

If, however, in addition to the magnetizing current caused by E_1, we force through the fields of the power motors a certain portion of the current from the field of the exciting motor having the phase of ϕ_1, then will ϕ_2 and E_2 be advanced in phase con-

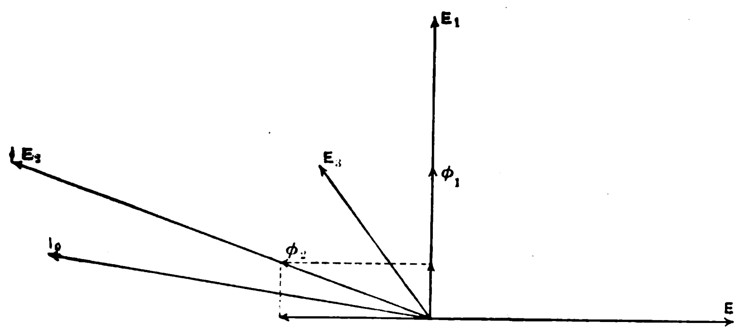

FIG. 2.

siderably, as in Fig. 2, and the resultant E_3 will lead E_2 and the current I_0 flowing may lag considerably behind E_3, and still be nearly in phase with E_2 or E_0, assuming a position between the two giving a good condition for returning power instead of volt-amperes to the line.

L. B. Stillwell: The importance of recuperation has not been recognized adequately by American railway engineers. Its importance, as Mr. Cooper states, is primarily due to the fact that it assists powerfully in reducing wear and tear of rolling stock equipment. The average cost of renewals of rolling stock of the railways of the United States to-day exceeds $250,000,000 per annum. Of that total, a large proportion, probably at least one-half, is due to the destruction of rolling stock by loss of control on heavy grades and by excessive wear and tear of wheels and brakes and strain of draft-gear. A number of years ago when the late Judge Cowan was president of the Baltimore & Ohio, this wear and tear of rolling stock loomed up in the road's cost of

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operation as so formidable an item that he and some of his assistants very seriously considered the problem of utilizing electricity to operate the heaviest of their mountain grade divisions. Messrs. Duncan & Hutchinson made an investigation and report at that time, and I recall that subsequently Judge Cowan expressed to me the opinion that the saving in cost of maintenance which could be effected by using the three-phase system on this division was of the greatest importance.

In this connection, the work that Mr. de Kando and his associates of the Ganz company have done is of great interest. The argument which Mr. de Kando uses in meeting the opposition of the railway operator who is of the opinion that it would be quite impossible to operate up grade and down grade at uniform speed is interesting. Mr. de Kando takes the position that the true limitation of speed, either in climbing or descending a mountain grade, is the curvature of the road, the limiting curves properly fixing the maximum speed. He argues that instead of climbing a grade at a speed of 20 miles an hour and descending it at 40 miles an hour the same result is attained in crossing the mountain if the locomotive be run at the average speed of 30 miles an hour. If 30 miles an hour be the permissible speed with reference to limiting curves nothing is lost, so far as schedule is concerned, and much is gained, in assuring the safety of the train in going down grade by adopting a system that absolutely holds the train to the speed that is predetermined as a safe limit.

Anyone who travels over mountain-grade divisions in this country and looks out of a car window usually sees the remains of at least one freight wreck, and the argument which Mr. de Kando makes is not fully met, in my judgment, by saying that it is necessary to operate at widely varying speeds in going down grades in order to attain the necessary average speeds. Undoubtedly this is the practice. The engineer will " let her out ", as he says, when he has a short tangent and will go downgrade at what he considers a safe speed, but the results are shown by the wrecks. It would be far safer, as far as the maintenance of rolling stock is concerned, to fix the limit speed for him in the office of the superintendent and provide a system which does not permit him to exceed the limit established.

As regards the interesting system of recuperation of power which Mr. Cooper has presented, I would suggest that the attempt has been made to go too far in obtaining variation of speed at the price of complication of switching apparatus. In my judgment it would be better to establish a narrower range of speeds for operation on mountain grades, and eliminate a considerable proportion of the switches illustrated in the diagrams. A tendency of single-phase equipment is toward an inordinate use of switching gear.

Recuperation involves, in general, an increase in the output of motors, since they are worked down grade as well as up grade. Probably in practical operation the difference would not be

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very material in respect to this point. It is customary now to add a second engine when a train reaches the foot of a mountain grade, and in general it would not greatly handicap mountain operation if the second locomotive were to accompany the train over the entire grade, being used to assist in holding back the train and restoring energy to the line in descent. Substantial compensation for the additional locomotive mileage involved would be obtained in the saving of power.

J. C. Lincoln: Has Mr. Cooper made experiments to determine how much more wear there is on the gears of this regeneration system than with the ordinary method now used in operating railroad motors, where the motors are used as motors only and never as generators?

William Cooper: As to the wear on the gears—of course that is purely a mechanical matter and it is self-evident that if the gears do work they will wear. The best example of that, I think, would be the traction brake on street cars, where the electric brake is used for traction purposes. In that case, of course, we find that the gears wear out faster than they would if only used as motors. They are bound to do that from the nature of the case. The amount of wear would be proportional to the amount they are used for regenerating purposes.

Mr. Stillwell's comment about the number of switches involved as shown in the diagrams needs a reply. Of course there are some other considerations which will determine how many switches are necessary, but from the standpoint of making assurance double sure, and having a system to operate without a hitch of any kind from a designer's standpoint, I incorporate a sufficient number of switches to cover any condition. Probably a case would arise where a very much smaller number would answer the purpose.

In regard to Mr. Slichter's point about shifting the phase relation of the generated electromotive force—I ask how he would produce the displacement of the electromotive force on the exciter field? It is simpler to displace the current in the exciter armature circuit than it is to displace the current in the field circuit of the exciter. That can be done by methods well known to the art of shifting the current in an alternating current system, by increasing resistances or inductance to get any predetermined relation.

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Discussion on "Some Power Transmission Economics", at Niagara Falls, N. Y., June 28, 1907.

(Subject to final revision for the Transactions.)

Chas. P. Steinmetz. This paper describes a construction suitable for power transmission where the utmost reliability is not necessary, but where cheapness is needed to make the installation feasible. It is desirable in all such discussions to give some clue of what is understood by " reliable " or " satisfactory " operation. In listening to statements of satisfactory operation of transmission lines, it will be found that " satisfactory operation " is a flexible expression; for what may seem to one engineer under certain conditions as satisfactory, may to another engineer, seem very unsatisfactory. For instance, the chief engineer of a large city told me a few days ago that in his city the power has not been off the low-tension bus-bar in fifteen years. In such a case a number of shutdowns averaging one shutdown per year, of five minutes or less duration, would be unsatisfactory operation; because if it should happen there probably would immediately be a legislative committee to investigate why it happened that some thousands of citizens were caught by the failure of the power in elevators midway between the floors of office buildings. In another instance, in a transmission line supplying power to a mining district, it may be perfectly satisfactory operation if the number of shutdowns averages not more than two per month, with perhaps a total duration of an average of twenty minutes per month. That may be perfectly satisfactory in that case.

It would seem desirable, then, for an engineer who makes a statement of this kind to preface his statement with something like this: I consider as the limits of a satisfactory operation a number of shutdowns averaging not more than two per month of a total duration of not more than twenty minutes per month; or I consider as the limits of satisfactory operation a number of shutdowns averaging not more than two per year of a total duration of not more than five minutes per year, whichever may be the case. Then we really could compare the cases intelligently, while now we really cannot do so.

The thing which brought this matter to my attention is that we have had so much discussion of what is proper to do for transmission at voltages above 60,000, and we have discussed transmission lines of 100,000 volts, and more than 100,000 volts, and, too, someone has asked the question, which has remained unanswered, whether there is anywhere in this country or anywhere else any transmission system in successful satisfactory commercial operation of 60,000 volts or more. The answer to the question would entirely depend on what one calls satisfactory operation. If satisfactory operation is to be judged from the experience of the city engineer in whose system the power had not been off the bus-bars for fifteen years, I do not think there is any such system, or will be for a long time. If by satisfactory

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operation is meant the case of the engineer who figures the time when the power is off the circuit in per cent. of the total time, and is satisfied if it is not more than one per cent. of the total time when there is no power, then there will be quite a number of systems in successful operation.

F. B. H. Paine: I think that Mr. Steinmetz asks too much of the engineer. I was brought up in a school where the use of the word "satisfactory" was prohibited. Manufacturing companies have eliminated that word from their vocabularies and so I think it would be necessary to understand, not so much what the engineer of the transmission company thought was satisfactory, as what each one of his patrons thought was satisfactory; I have yet to find a unanimity of opinion anywhere as to what satisfactory service may be.

The great value of Mr. Baum's paper is in bringing out strongly the great difference in transmission practice of the West and the East. I have recently made an extended trip in the West in order to harmonize, if I could, the conflicting statements as to the availability of certain apparatus and methods for high-voltage transmission that are not regarded in this part of the country as permissible, yet I knew to have been in successful operation in the West. The most striking differences which Mr. Baum brings out in his paper are two: the use of the ground as a return for high voltages, and the fact not expressly stated in his paper, that no automatic apparatus is used on their system. The fact that no automatic apparatus is used permits the use of a class of switching and other line apparatus, even on a system of that magnitude, which would be utterly impracticable on a system of lesser magnitude where automatic apparatus is used. The oil-switches that are shown here are excellently constructed, but to one who is accustomed to the immense switches used for 60,000-volt service in the East they are astonishing; they only cost $200 or $300, and we are accustomed to pay $1500 to for our switches. I attribute the successful use of these $2500 cheaper well made switches to the fact that they are non-automatic and are used only under more or less ordinary operating conditions, not emergency conditions. They are used furthermore, on long transmission lines with comparatively small conductors and the most complex system that is imaginable. They are extremely useful devices; they ought to be available for special service in the East, but they would not do to control large transmission systems with large conductors and large generating units behind them.

The use of the ground as a conductor I have supposed to be open to serious objections. I should suppose this to be the case particularly, as in their case, where it is used for 60,000 volts, for 12,000 volts, and 2300 volts and how many other voltages I do not know. I wish that Mr. Steinmetz and Mr. Scott would speak on that phase of the subject.

There are a good many things described in the paper that

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indicate a construction applicable only to a country free from extremely high winds and sleet. The very ingenious pole-line construction would not be usable in such a climate as New York, and this should be fully appreciated. Mr. Baum regards two independent pole lines entering the city from different directions as being more reliable than two circuits on an individual tower line, or two circuits each on their own tower lines, presumably supplying power from the same source. The difficulty in building up one circuit out of two, two wires on one, and one on the other line is very much increased and made almost impracticable if the circuits themselves are distant from each other and if each line feeds different customers. Lines in the same vicinity are equally likely to injury from lightning whether they are adjacent or two or three miles apart.

The reason for the use of different tensions in the three wires on a pole line is not obvious, and I was not able while in the West to ascertain any satisfactory reason for the practice. Unbalanced strains on one fragile structure are mechanically very undesirable.

The reason given by those in charge of various lines was that it was found impossible to string the wires sufficiently close to the same tension, therefore in a wind storm the different periodicity of the swing of three wires would ultimately bring them together. I think a more careful inspection of the lines during construction would make it possible to string them to the same tension. On our 400 miles of line no one has ever discovered a tendency of the cables to swing together. We use a seven-foot triangle, with spans normally at 550 feet and ranging up to 1200 feet, 1200 feet being approximately the longest span we have. We find the cables swing synchronously and are sluggish in their movement when subject to sudden gusts of wind.

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Discussion on "Single-Phase High-Tension Power Transmission", at Niagara Falls, N. Y., June 28, 1907.

(*Subject to final revision for the Transactions.*)

Chas. P. Steinmetz: In this paper Mr. Young gives a discussion of the relative economy of the different transmission systems. In bygone years, considerable discussion took place on this point, and it was shown that the three-phase system requires only 75 per cent. of the copper of a single-phase system or a four-wire two-phase system, on the basis of equal maximum electrostatic stress. With the change of industrial conditions, such conclusions will have to be revised. When the matter was discussed before, when the statements were correct, because in those early days all electrical circuits were operated as isolated systems without grounded neutral, and in that case the voltage which came into consideration was the voltage from conductor to conductor, across two insulators, and in that case the three-phase system has an advantage of 25 per cent. in copper.

Now, with voltages of 60,000 or more, it is almost always the custom to ground the neutral, and in this case the maximum stress is from the conductor, over a single insulator to ground, corresponding to the voltage which in the single-phase system is the voltage between the conductors divided by two, or half the line voltage. In the three-phase system the voltage between the conductors is divided by $\sqrt{3}$, or the *Y* voltage: in other words, when operating with grounded neutral, all systems, single-phase, two-phase, or three-phase are exactly alike in their copper economy. They are all combinations or multiples of single-phase systems with grounded return and zero resistance in the return. All these systems, as we know, theoretically can be considered and are considered as a number of single-phase systems, each system being one of the transmission wires, returned over the ground with zero resistance in the ground. The statement that the three-phase system has an economy in copper of 25 per cent. is not correct any more for the high potential line with grounded neutral, but at present with grounded neutral the three-phase system does not offer any advantage in copper economy over the single-phase or four-wire two-phase system. The advantage of the polyphase system over the single-phase system is only the greater usefulness of polyphase power, since the largest part of the power is always used for synchronous motors, induction motors, synchronous converters, etc. The advantage of the three-phase system over the two-phase system is the advantage of three wires over four wires. This is what upholds the three-phase system at present.

In comparing the three-phase or single-phase system with direct current high-tension transmission it was pointed out in the early days that they cannot be compared as regards copper economy, on the basis of maximum voltage or effective voltage, because one stress is alternating with the average equaling zero, the other stress is unidirectional, and so all those effects of the

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electrical stress which are unidirectional, exist to a very small extent only in the alternating current system, while prominent in the direct current system, and all those effects which depend on instantaneous voltage are greater in the alternating current system. So direct current high-tension and alternating current high-tension cannot directly be compared on the basis of some voltage, average, effective, maximum, or whatever it may be, but require a further investigation which the future will give; and the future will indicate whether the direct current high potential transmission should be reintroduced to any appreciable extent, which by the way I do not believe.

E. H. Schwarz: It is obvious that in single-phase transmission, single-phase alternators might be used, and I would like to know where there is a low power-factor due to a heavy overload, whether the armature reaction in a single-phase machine knocks down the voltage less than in a three-phase machine?

Chas. P. Steinmetz: The opposite is the case. In a single-phase machine the armature reaction lowers the voltage more at heavy load and low power-factor than in the polyphase machine, and not only lowers the voltage but also changes the wave shape by superimposing the triple harmonic on the main wave. The result is that a machine cannot be operated at the same output single-phase that it can be operated polyphase; that is, a certain type and size of machine when built single-phase must be rated at the lower output, probably about three-quarters of that when built as a polyphase machine.

E. H. Schwarz: In making short-circuit tests on three-phase and single-phase machines, I have noticed that it takes less field current in single than in three-phase. I thought that was due to the fact that in the three-phase alternator the maximum current in one phase would demagnetize the field at a time when the other phases should be generating a certain voltage, while in the single-phase alternator the demagnetization due to maximum current could only affect the one phase of the machine, and since the voltage would be zero at this time, the demagnetization would have no effect upon it.

Chas. P. Steinmetz: If there is a three-phase machine and it is short-circuited single-phase, it will require less excitation for the same short-circuit current as when short-circuiting the machine polyphase. But the same current in the single-phase machine corresponds to less power, since for the same power the single-phase current should be $\sqrt{3}$ times the three-phase current; while with the same current the field excitation and the regulation may be better single-phase, with the same power; that is, $\sqrt{3}$ times as much single-phase as three-phase current. The regulation single-phase must be very much poorer than three-phase; in other words, at equal output, other things being the same, the single-phase machine gives poorer regulation and also a greater heating than the three-phase machine. Inversely,

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to get approximately the same regulation and heating in a single-phase machine, the output has to be reduced considerably below that which the same machine would have as a polyphase machine.

C. T. Wilkinson (by letter): The feeling aroused not only in Europe but also in this country in regard to the high-tension direct current system of transmission devised by Mr. Thury is illustrated by Mr. Young's interesting paper. As one who has observed somewhat carefully the operation of this system I beg to offer the following comments.

First, and possibly the most important consideration, is telephonic and telegraphic disturbances, due to the grounding proposed by Mr. Young. Where this one-phase system operates under normal conditions it is uncertain whether serious trouble of this character will develop, but it seems highly probable that when running under the emergency condition proposed by Mr. Young in a case of a breakdown of one line that very serious difficulty would be expected.

The connection of the two high-tension transformer windings in multiple, as shown in Fig. 3, doubles the current of the transmission line and, therefore, increases the losses four times while it is possible that regulation would be seriously interfered with and that considerable trouble might be experienced due to hunting or surging of the single-phase synchronous motor-generator sets at the receiving end.

In the case of a ground on the direct-current system, Mr. Young states that one-half the motor-generators will stop. In this connection attention may be drawn to the method of building the Thury sets in semi-groups, each semi-group containing two armatures on the same shaft which are connected in series, the idea being that if the station capacity is to be increased at any time, it can be done by connecting these two armatures in multiple, thus doubling the current and halving the voltage. While, of course, the switching arrangements should enable this to be done rapidly in case of breakdown, this would somewhat reduce the present remarkable simplicity of the Thury system. This method would solve the difficulty quite satisfactorily, though of course the line losses would be doubled. The semi-groups being thus connected in multiple, they would all be thrown across between the earth and the remaining line.

Perhaps, it is worth while considering the arrangement Mr. Thury has devised in case a breakdown occurs where it is not desirable to ground the whole line. In these cases he places the transmission line (as in the case of the transmission from Moutiers to Lyon) in several sections, providing what are called "earthing-cabins" at intervals in order that only the broken section of the line need be earthed. With regard to Fig. 4, it seems at first sight as though greater simplicity ought to be obtained, since a large number of high-tension large rupture capacity switches must be employed. Further it is not quite clear why four transformer tanks must be used; would not two sepa-

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rate tanks be ample with a third in reserve? Possibly Mr. Young would be kind enough to explain this matter a little more fully.

When comparing this system with the direct current system it must be remembered that it is a comparatively easy matter to guard the latter system from lightning trouble; but in spite of the high advance made in all types of lightning arresters in recent years, trouble is occasionally experienced with alternating-current transmission.

The further troubles due to capacity and inductance need only be referred to, since it is, of course, thoroughly appreciated that their absence is an inherent advantage of the direct-current system. It might be well, however, to hold in mind that with high voltages the direct-current system allows the line wires to be somewhat closer together with resulting economy in transmission towers.

G. T. Fielding Jr. (by letter): While engineering practice sometimes drifts in the wrong direction, it seems as though there are legitimate reasons for abandonment of the original single-phase machinery and systems, passing of the quarter phase, and then gradually but surely settling down to three phase.

Engineers and station operators have not a very friendly feeling toward single-phase machinery, especially in units of appreciable capacity. The heavy vibration under load, the excessively large exciting current with inductive loads, and inferior regulation do not add in its favor. The most serious drawback to the single-phase synchronous motor is the lack of starting torque, and with units of large sizes difficulties in bringing up the speed and synchronizing in would be anticipated.

A single-phase motor caused to drop out of step by momentary overload or any passing cause cannot of itself regain its synchronism as can a three-phase machine, but will quickly come to rest.

The cost of a single-phase machine would probably be about 20% more than a three-phase type if figured on an all around equal basis.

Though it is said that the switching would be simpler with the single-phase system, it is not evident from the writer's layout in Fig. 4. It would seem that the half transformer might be arranged to connect in series rather than in multiple in case of the failure of one line. The amount of power transmitted upon the same basis could not be doubled by making the multiple connection, and if the line insulators were based on a liberal safety-factor the series combination should reasonably be maintained until repairs are made on the damaged line.

While Mr. Young calls to attention some interesting points in making comparisons, it would seem that the disadvantages of single-phase machinery would weigh heavily upon whatever merits there may be in the transmission.

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Discussion on "Lightning-Arresters", at Niagara Falls, N. Y., June 25, 1907.

(*Subject to final revision for the Transactions.*)

N. J. Neall: Without knowing what Mr. Thomas would set forth in his paper, I find that I could take paragraph 4 of his recommendations as a basis for the contribution to the Institute which I make this evening.

It is safe to say that the commercial testing of lightning-arresters to-day by the manufacturers is not carried much beyond 2500 volts in the factories, nor above 25,000 volts in practice. The long term of years during which 25,000-volt lightning-arresters have now been in service has enabled arresters up to this voltage to become fairly satisfactory. But for voltages above this it is perfectly safe to assert that no manufacturing company to-day could make any such tests on lightning-arresters as have been stipulated by Professor Creighton and Mr. Thomas. One of the reasons for this is the large apparatus required, its costliness, and the difficulty of placing it in the factory—where it would hold up considerable work going through for customers. It was for this reason that last year the method which I have proposed was devised in order that a collection of various well-known forms of lightning protective appaiatus for station and for line service might be given a service test to determine their true merits. The principle of the test consists in passing a static discharge over the gaps of the lightning-arrester in such a way as to form a path for either a passage to ground of the stored capacity of the system or for such short-circuits as may be desired.

Those of us who are familiar with the practices of wireless telegraphy will recognize in the method a form which has been employed in that connection, but until I discussed the proposed test with Professor Reginald Fessenden in another connection, I was not aware that such was the case. I believe, however, that the application in this instance is original with me.

I would lay particular emphasis upon the opportunity which this test will now give the operator as well as the manufacturer to test out the arresters in practice, and for this reason I cannot too heartily urge the coöperation of the manufacturer and the operator to the end that more positive information be obtained as to lightning protective apparatus operation.

Chas. P. Steinmetz: Professor Creighton's paper is essentially positive. He discusses all those tests which it is desirable to make on lightning protective apparatus so as to assure their satisfactoıy operation, their operativeness as far as our present knowledge of lightning phenomena goes. Mr. Thomas' paper shows us what tests we should make, tests that are very difficult to make, and in many cases almost impossible except with special facilities.

I believe the conclusion to be drawn from these two papers is that the testing of a lightning-arrester is not the same as the

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testing of other electrical apparatus. Other apparatus can be tested before the customer and approved, but with the lightning-arrester it is essentially a test of a type to be made on one or a few samples of the arrester, to show whether it—or rather a duplicate of it—will probably be able to cope with the lightning phenomena. After carrying out all of these tests, for instance to determine the limits of the discharge capacity, there will probably be not much left of that particular lightning-arrester. Hence the testing of the lightning-arresters is somewhat similar to that of incandescent lamps. Incandescent lamps cannot be completely tested for life without destruction, and only a certain small percentage of the product is tested, and the rest judged by the performance of the tested (and destroyed) percentage.

The first attempt to test lightning-arresters similar to standard apparatus is given in Mr. Neall's paper. Naturally, such a test is to some extent rather dangerous to the arrester as well as to the system. It is the starting of a discharge of an induction coil. If, instead of a vibrator operating the induction coil, we operate it by a Wehnelt interrupter, or substitute in its place a Tesla transformer to set off the discharge, it gives a very good way of testing the endurance of the arrester for the recurrent surge as described by Professor Creighton. That means that in all probability in the case of all the commercial arresters at present in use it would be from a few minutes to a few seconds before they would go up in conflagration, because most arresters are built to cope with transitory surge oscillations, transient discharges, and not with recurrent surges. This method of testing by sending a single impulse through, by closing the switch of the Rhumkoff coil, and immediately opening it, will give a single discharge or a few successive discharges; but by closing the switch and keeping it closed, with the rapidly operating induction coil or Tesla transformer it will give a recurrent surge, such as is met with in practice with a spark discharge between the cable conductor and the cable armor, or with the spark discharge from an isolated transmission line to ground through a broken insulator.

Such a recurrent surge as we know now is not taken care of by most types of lightning-arrester, but requires additional protective devices, as explained by Professor Creighton. It requires an aluminum cell permanently connected from line to ground. That brings up the second point to which I desire to call your attention and that is that all these statements of tests with different forms of lightning-arresters possibly may have to be modified slightly here and there. For instance, to test the discharge voltage, as laid out by Mr. Thomas, we cannot always apply the Institute test of gradually raising the voltage until the discharge takes place, and then keep it on for a minute. In some types of arrester, as exemplified by the water jet—which we are told gives such good results abroad, especially in countries where lightning is not particularly severe— or the aluminum ar-

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rester, there is no definite discharge voltage. Their discharge voltage is the normal operating voltage, because they continuously carry a small current and in such case the test would have to be modified. I especially refer to the aluminum arrester, because in this country where lightning is rather severe I do not think that the water jet would be considered as particularly useful. In this case the test may be made by inserting in series with the lightning-arrester the short-circuited secondary of a transformer, and then suddenly opening the secondary circuit, while energizing the primary with impressed electromotive force; that is, suddenly raising the voltage on the lightning-arrester by a certain definite value, say 5%, or 10%, or 50%, and then measuring the instantaneous rush of the discharge current. The discharge current, even if the rise of voltage is moderate, say 10%, may be very large in the first moment, but rapidly dies out, the lightning-arrester adjusting itself to the higher voltage. Some other modifications of tests would also have to be made, which would be obvious to the one who studies the particular lightning-arrester. In general, the conclusion is that the testing of the lightning-arrester, to get absolute results on its probable performance in actual operation, is not so simple as testing other apparatus, generators, etc., but requires the coöperation of the customer with the manufacturer and also requires special facilities, quite elaborate facilities, really to get a complete and reasonable and effective test.

P. H. Thomas: I am surprised that none of the manufacturers of commercial lightning-arresters has made a protest against the rather uncertain and indefinite tests here proposed for Institute sanction, as I am inclined to be sceptical about the wisdom of the Institute's attempting to standardize lightning-arrester tests at the present time. The Institute should be very careful about approving methods of testing lightning-arresters that cannot be conducted by engineers of ordinary experience, methods by which such engineers would not usually be able to produce identical results. There are not more than one or two of the tests proposed that can be so conducted by the average engineer. Mr. Creighton's recommendations seem to be intended for individual research by experts and designers of lightning-arresters, rather than tests to be undertaken by commercial engineers.

I feel also doubtful about the wisdom of making any more definitions at present. It is hard to keep track of definitions made by the international societies and conventions: and if we make any more I think it will lead to complete confusion.

It is too soon to attempt to make standard rules for testing electrolytic arresters. There is a good deal of laboratory information, perhaps, and a good deal of inference as to what their characteristics will turn out to be; but until a considerable number of engineers become pretty familiar with them, and the plants in which they are installed have seen more experience,

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I think we should refrain from adopting any standard tests. I do not wish to make any insinuations about the value of the electrolytic arrester, but I think we should go slow on general principles before standardizing tests.

Mr. Neall's paper shows an ingenious arrangement and one which might work conveniently in some cases, provided the induction coil will cause sparking over the gap, which I think is doubtful in most cases. As Dr. Steinmetz has pointed out, it is necessary to have a single spark at a time, not a series of sparks more extended, except in the case of an endurance test. With one or two exceptions, relative tests are the only valuable tests. It is not possible to say that the arrester has so many absolute units of protective power.

W. S. Lee: If some system could be devised for testing the lightning-arresters where installed it would be an excellent thing, and I think it should be given some consideration as it would help out the man who thinks he has got an arrester but really has not. We should have some test, if possible, which could be made periodically, to find out whether the arresters on lines are good or useless. Having to contend with a great deal of trouble every year with lightning-arresters, I think the time has come when some reliable tests should be devised which could be applied to the arresters while they are in service.

N. J. Neall: In answer to Professor Creighton's question—the requisite spark strong enough for a given discharge has not been fully determined. For low-voltage preliminary experiments it was easy to obtain more spark than was actually necessary in order to have the arc take the spark as a bridge.

Another important consideration, discovered almost at the outset, is the impossibility of obtaining a spark from gaps to ground if the condenser heads are connected directly to the high-tension feeders, because the power in the high-tension system is sufficient to hold the condenser charged. It is for this reason that connection is made to the middle point of the series of gaps between the line and ground in order that the discharge may have full play in both directions.

I should like to make the following suggestions in connection with the papers by Messrs. Creighton and Thomas.

1. *Nomenclature.* The names, definitions, and recent classification of lightning-arrester characteristics while entirely proper from the standpoint of theory, strike me as being unduly elaborate and unnecessary for the purpose for which standardization rules were originated. It seems to me that nomenclature can be overdone, not to speak of misleading the general manufacturer and operator who is not necessarily a technician.

Practical lightning development and testing should be kept as simple as possible in order to free it from any mystery which can be so easily attached to this branch of the art.

2. *Apparatus.* It will be observed that the methods pro-

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posed for the development of lightning protective apparatus, even under the most favorable laboratory conditions, do not permit a thorough investigation of the devices under operation much above 5000 volts.

Practical application of lightning protective apparatus is now fairly well established up to 30,000 volts. What is needed is information as to its behavior at a higher voltage, 50,000 volts and so on, so that in selecting any standard test in its development this difference in the character of the service should be borne fully in mind.

As a matter of fact the only test of final value is a practical one. A method to this end has been described previously in the PROCEEDINGS. It consists in a careful observation by means of tell-tale papers as to the operation of all protective apparatus on a given system so that any recommendations by the Institute under the head of Standardization Rules should give some mention of this.

3. *Tests proposed.* I heartily approve of the tests proposed by Mr. Thomas as being practical. While they do not cover the case absolutely, they furnish all the information that would usually be required.

If to his proposed tests, a further one should be added to cover investigation by means of tell-tale papers over a long period, there should be sufficient data to eliminate considerable uncertainty.

4. *Needle-point spark-gap.* It seems to me that the most serious danger to the general engineering field lies in the proposed "standardization" of the needle-point spark-gap.

Those members of the Institute who have studied spark-gap performance know that it is very difficult to check the curve which has so far been accepted as standard. Now merely to extend the range of readings on this curve at higher voltages without a thorough study of the phenomena entailed strikes me not only as injudicious, but likely to destroy the prestige which should attend the publication of any data of this character.

It is not my intention to go into the characteristics of spark-gaps of various forms for voltage measurements, since this would well be the subject of a number of papers. It is of as much importance as contributions on lightning-arrester tests. I would therefore respectfully protest against the unqualified use of this form of gap, particularly for very high voltages as at present proposed; in its place I would substitute the gap made with spherical noses backed by metallic discs in order to reduce the opening for a given voltage as well as to straighten and fix the curve therefore.

Charles E. Waddell (by letter): The mountain and Piedmont districts of North Carolina are subject to severe electrical storms of frequent occurrence. On the breaking of winter in the latter part of February or the early part of March, the first destructive storms usually occur; then follows a lapse until the

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latter part of May or early June, at which time they are at their worst, and from which climax there is a gradual diminution in violence until, early in September, the electrical storms practically cease.

As it is the expressed purpose of the Institute to gather all information pertaining to the subject of lightning, thereby hoping to correlate sufficient data to solve the problem of protection, it is purposed in this paper to recite two instances a little out of the ordinary.

The plant that has suffered more than any other in the mountains is that of the Haywood Power Company on the Pigeon river, twelve miles from Waynesville. The equipment consists of a 400-kw. three-phase, 60-cycle, 13,000-volt hydroelectric unit. The 12-mile transmission line is composed of three No. 2 B. & S. aluminum cables, supported on Thomas 5-T insulators, and on wood poles spaced 200 feet apart. The line runs over mountain ranges and across valleys, touching altitudes of 4000 or 5000 feet.

The lightning protection originally installed was of the highest grade of one of the well-known arresters. Some little difficulty was experienced in obtaining a good "ground", but after this was overcome the management felt perfectly safe. The opening of the following season was, however, heralded by the destruction of coil after coil in the generator, until at the time the author was called in, out of 54 coils in the armature 40 had been burned out and repaired, and the machine was then running with 13 coils out. Matters had reached a point where on the slightest manifestation of an electrical disturbance the plant was shut down.

An examination revealed the singular fact that not a single coil had grounded on the frame, but had in every instance ruptured on the ends. While in the station a powerful arrester discharge took place, and it was observed that the polyphase electrostatic ground detector which had previously been in a quiescent state became most unstable, erratically fluctuating first one way and then the other, and this was followed in a few moments by the giving way of a coil, and the inevitable shutdown.

The writer concluded that the rupture was due to a static stress that slowly built up, and that the inductive discharge from the electrical storm merely intensified the effect; this opinion was sustained by the attendant's statement, that ruptures occurred when no storm conditions prevailed, and that the line was frequently observed to deliver a brush-discharge at the wire entrance.

Inspection of the generator disclosed the fact that the armature was Y-connected. It was decided to ground the neutral point, consequently reducing the potential between each line wire and the earth to 7500 volts.

The arresters were of a design suited to a maximum potential of 18,000 volts and were connected as shown in Fig. 1.

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Experience in a number of cases leads the writer to the conviction that it is as necessary to provide a path for a free discharge between the lines themselves as it is to provide a path

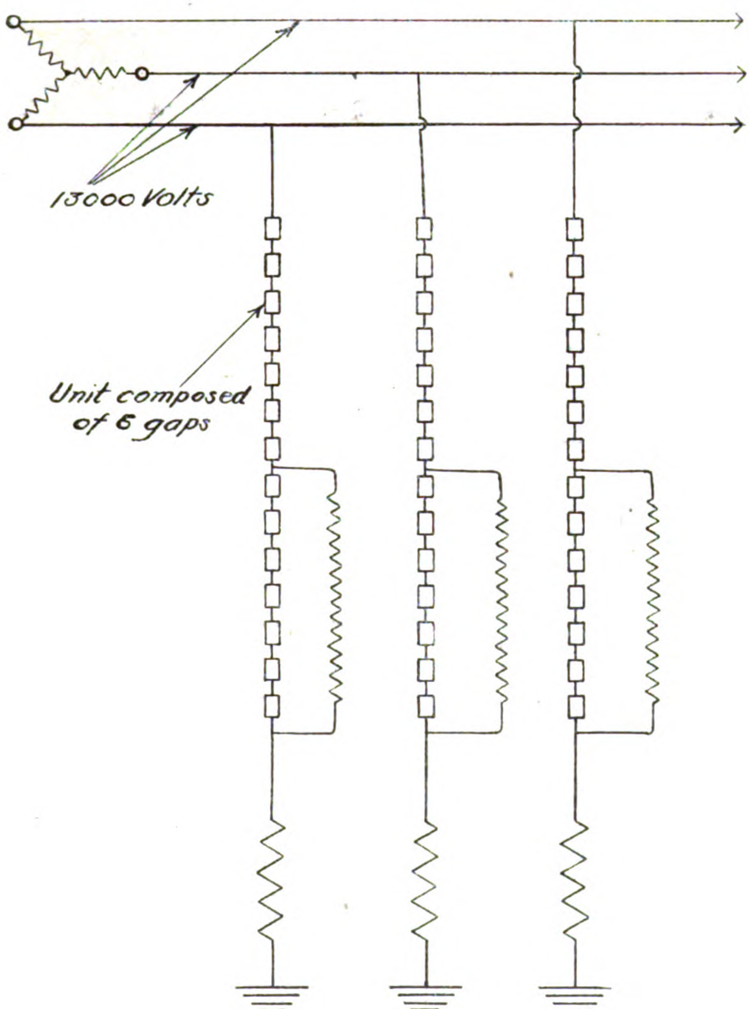

Fig. 1.

to the earth, it was therefore determined to modify the arrester connection, making the changes shown in Fig. 2, and the result was that immunity was obtained.

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The coils breaking down on the ends between turns, apparently indicating no disposition to ground, and avoiding puncture in the slots, would seem to indicate that the concentrated magnetic field, with the presence of iron, afforded a repelling effect, driving the static charge as far away as possible.

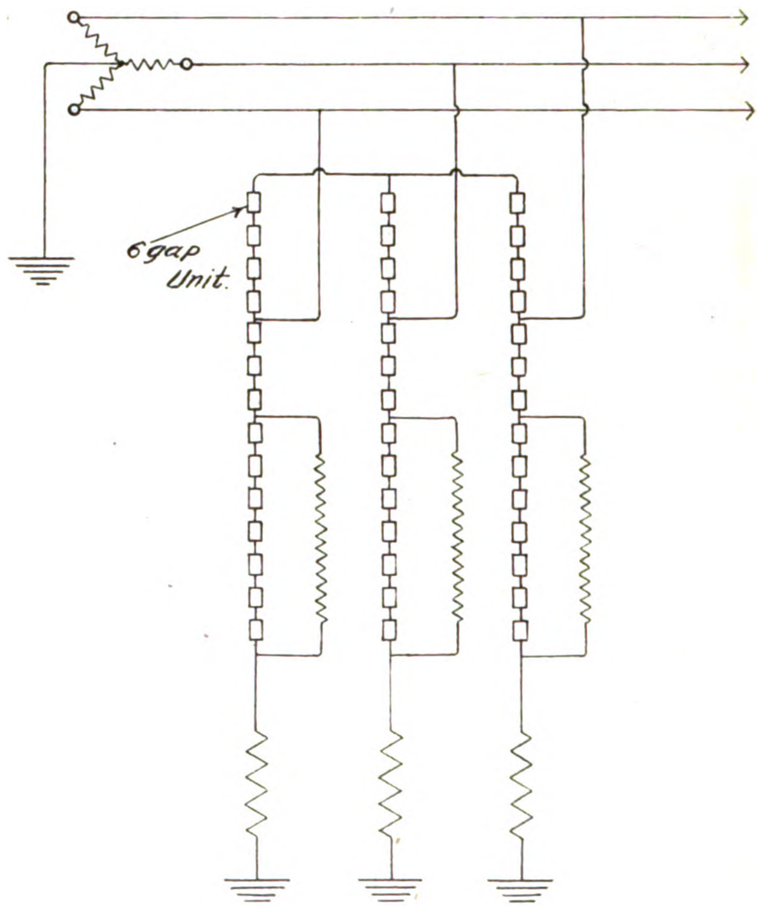

Fig 2

The second case is not solely a lightning discharge but is more complicated and may in part be attributed to high-potential oscillations or waves.

Included in the Weaver Power Company's distribution system is the Elk Mountain line, a circuit that is in all less than a mile

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long, which supplies mills in the vicinity of the power house, and the Biltmore line, a circuit nine miles long supplying at that time the Biltmore sub-station only. Both circuits had been in service for about a year and had given no trouble, the line potential being but 6600 volts and the insulators Locke's No. 298.

The transformers at Biltmore were connected in delta with a spark-gap on one leg of the secondary winding. In making some changes at the Elk Mountain mills it was decided to connect the transformers in Y. The neutral was not grounded.

Shortly thereafter a storm occurred, and during its progress an insulator and cross-arm were destroyed on the Elk Mountain line. Nothing was thought of the incident, a defective insulator being assigned as the cause; but the second, third, and fourth repetition of the trouble led to the conclusion that the insulators were not at fault, and that a more subtle cause was responsible.

Not long after the lightning season was over, an underground cable broke down on the Biltmore distribution system, followed, as it always is, by a continuous discharge on the secondary spark-gap. While this was occurring, the main plant telephoned that an arm and insulator were burning on the Elk Mountain line. The discharge at Biltmore was then saddled with the responsibility, and it was decided to provide the neutral of the transformers at the Elk Mountain mills with a spark-gap. This done, it was observed that when one line discharged the other inevitably followed. Since that time no more insulators have given way.

In each of the foregoing instances stress was purposely laid on the type of insulator In the case of the Haywood Power company the insulator was of a pattern that afforded very little leakage. The insulator of the Weaver Power Company affords a considerable leakage. The lines of the North Carolina Power Company parallel those of the Weaver Power Company, and are also equipped with an insulator on which the leakage is negligible.

With the exception of a few potential transformers destroyed when the plant first started, and the above trouble, the Weaver company has been practically safe from lightning troubles, while the other two concerns have experienced not a little inconvenience and loss. In view of these circumstances it would seem not an unreasonable conclusion that a slight leakage distributed over an entire distribution system affords considerable protection against static discharges, and that occasionally by the merest accident a condition of this kind is obtained.

Where violent discharges have passed over the arresters in the Weaver Power Company's station in every case that was investigated it was found that such discharges had occurred immediately before rain started to fall, and that once the insulators, arms, and poles were wet the discharges became less

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frequent and less severe, a fact that in the author's opinion tends to confirm the above theory.

In justice to the manufacturers of the insulators, it should be stated that the existence of leakage on the particular type is no reflection on the quality, for they are in every respect eminently satisfactory, but is due to the use of a type scarcely large enough for the service.

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THE RATIO OF HEATING SURFACE TO GRATE SURFACE AS A FACTOR IN POWER PLANT DESIGN

BY WALTER S. FINLAY, JR.

Power plant design, in its modern development, is controlled solely by the specific application of general laws modified and moulded to suit special requirements. To attempt the construction of a comprehensive ruling from the results of a particular line of investigation in some particular plant, and then to advise the general use of such ruling as conducive to economical operation, would cause confusion, possibly resulting in a wholesale rejection of the good with the bad. However, the value of specific results and their publication lie in the opening up of a line of technical thought, or in adding information to some subject, from which specific deductions or particular application may be made.

The results obtained in the investigation which was primarily the foundation of this paper, should be looked upon merely as specific, but whose bearing upon the general subject by means of a general development, may be of value, particularly in certain new phases of plant design.

As a fundamental and almost initial point of attack in the comprehensive subject of steam power-plant design, the ratio,

$$\frac{\text{heating surface}}{\text{grate surface}}$$

has been a value fixed from the beginning of results of commercial usage, and the expression of the same in empyrical formulas or figures suited to the requirements of this or that designer, builder, or manufacturer.

A summation of practice from early engineering times to

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values developed by the most modern idea, gives a great range to this ratio; namely, from the extreme value as advised by Dalton in 1839 of ten to one, to modern values up to seventy to one used, not only in locomotive, but even in power-plant practice. Of course the primary object in view has already been the adaptation of values to produce the maximum useful effect; but the question now arises as to whether or not, "maximum useful effect" is not being interpreted as maximum economical efficiency with reference to fuel only, as a primary consideration, and with an undue subordination of total plant costs. By total plant costs are meant, of course, the combined fixed charges resulting from interest on plant investment, depreciation, taxes, etc., and operation and maintenance charges.

Properly to investigate the subject in its particular applications would require an extremely tedious and complicated study of innumerable individual requirements; but for a general survey assumptions based upon commonly accepted values will suffice to direct the attention to the point involved.

Assuming a plant first cost of $125.00 per kilowatt; equipment, including turbo-generators, boilers equipped with stokers, with, say, sixty to one ratio, the following relative costs may be assumed:

Total cost per kilowatt.............	$125.00	100 %
Building " "	43.75	35 %
Boilers " "	6.875	5.5 %
Grates " "	1.75	1.4 %
Piping " "	5.625	4.5 %
Coal-handling apparatus per kilowatt.....	2.30	1.84%
Balance of equipment..................	64.70	

The value of the building as assumed might be considered low, particularly in the case of a turbine plant; boiler cost is possibly average; grates high—a stoker valuation; piping value is about average.

Assuming as a fair value for determining fixed charges: interest on investment, 5%; depreciation, 6%; taxes and insurance, 1%, then the total fixed-charge rate would equal 12%.

Upon bases of load-factor and charges, a curve has been drawn showing the relative value of the fixed charges over a range of factor variation from approximately 3% to 100%, in the case of the plant as assumed. (Curve A, Fig. 1.)

To determine total charges, the variation of maintenance and

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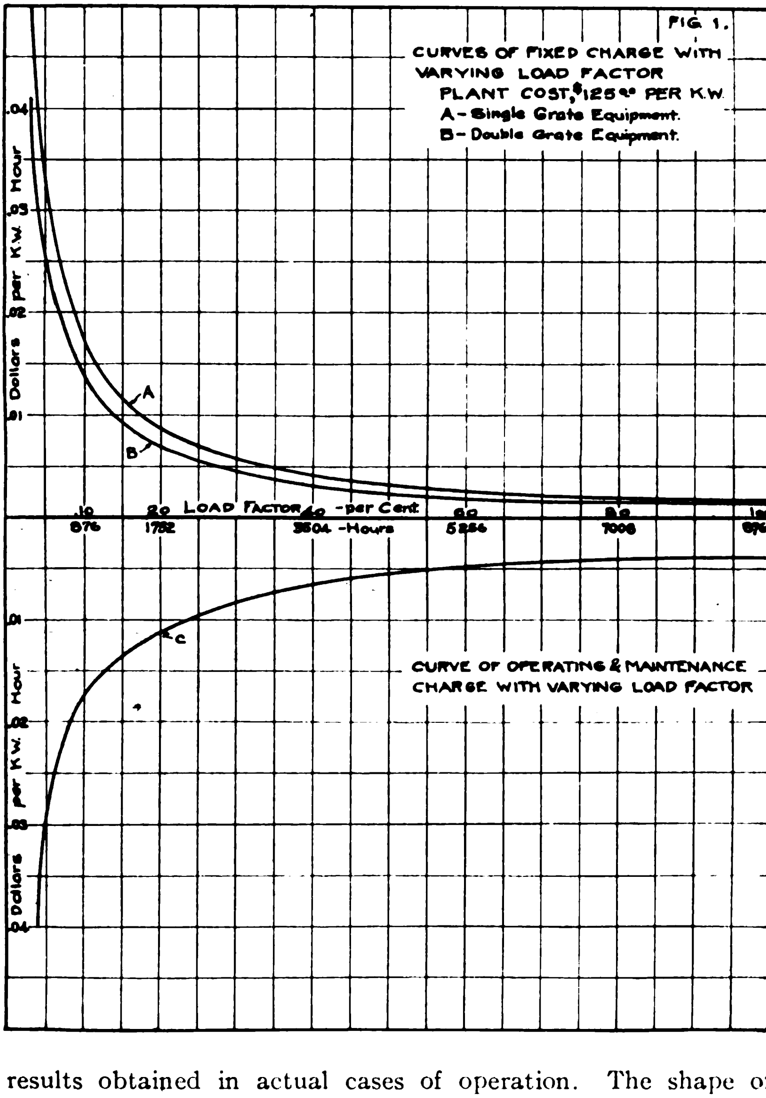
operation charges, relative to load-factor, must also be considered. It is rather difficult to assume this curve, as conditions in this respect vary rather widely. However, Curve C, Fig. 1, has been drawn through points located by comparative

FIG. 1.



results obtained in actual cases of operation. The shape of the curve will practically be constant for any figure which may be assumed, and its relation to the general results will be such that the value of the principle involved will be unaffected.

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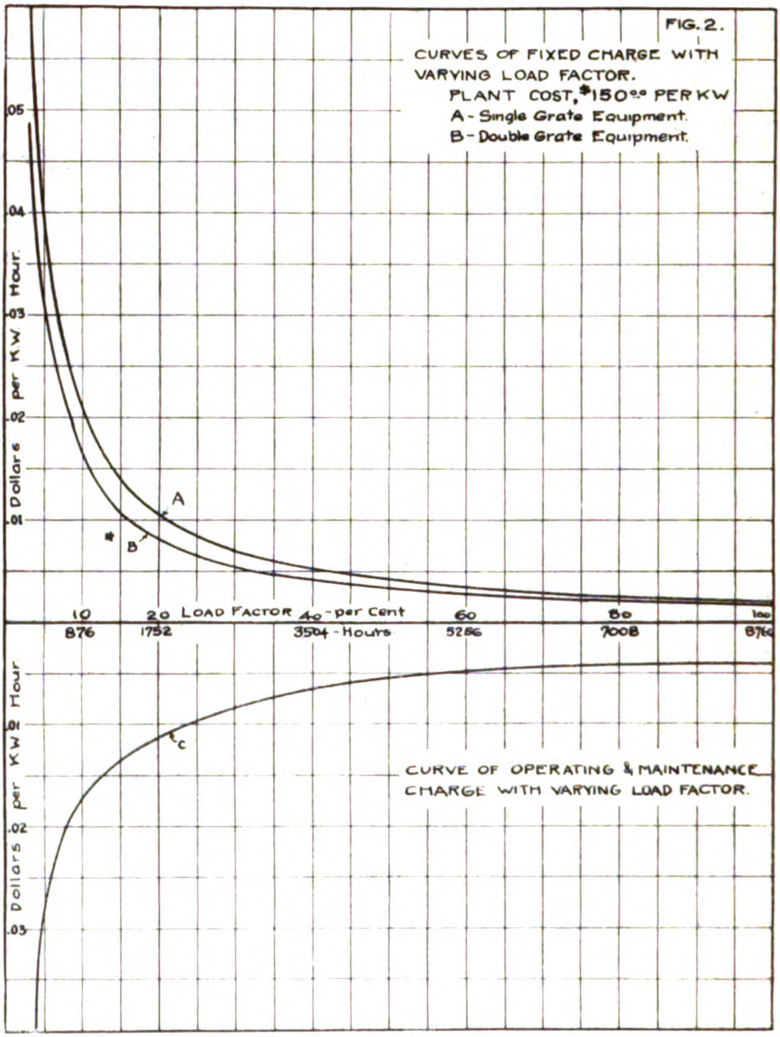
The sum of the ordinates between the two curves gives total charges per kilowatt-hour.

In a reconsideration of the plant design as affecting first



cost, the natural method of procedure is to consider separately each item involved.

1. *Building.* In turbo-generator plant design, it is a generally accepted rule that total plant dimensions are controlled by boiler-room dimensions; that, for instance, a diminution in

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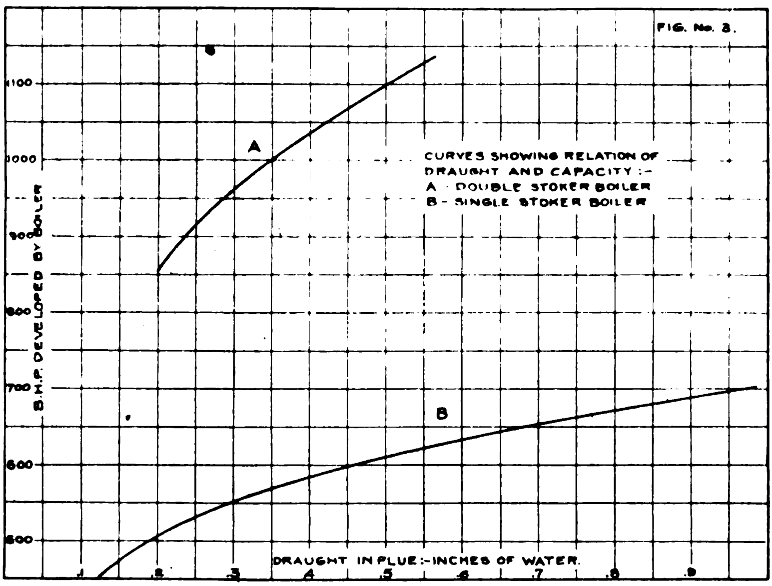
the actual size of the boiler room may be accompanied by a proportional diminution in the size of the turbine-room, the output remaining the same. The methods of accomplishing such results are perhaps various; change in size of units, difference in type, closer grouping of units, etc.

2. *Boilers*. The consideration of this feature is naturally interlinked with the subject of "*Grates*" and the two can better be discussed together.

Rules of boiler-practice have been derived chiefly, if not entirely, by experiment and investigation; and those rules



validated only by general acceptance can be quoted as bases for argument. Such a law is the following one:

All other conditions remaining constant, capacity developed is, with slight modifications, in direct ratio to the area of the active grate surface. An increase in capacity—heating surface remaining constant—caused by an increase in grate area, is accompanied by a loss in economical evaporation, due to the increased temperature of the escaping gases.

This loss in economy is the fundamental factor which must necessarily be the object of a careful study, involving the complete investigation of the heat interchanges taking place in a

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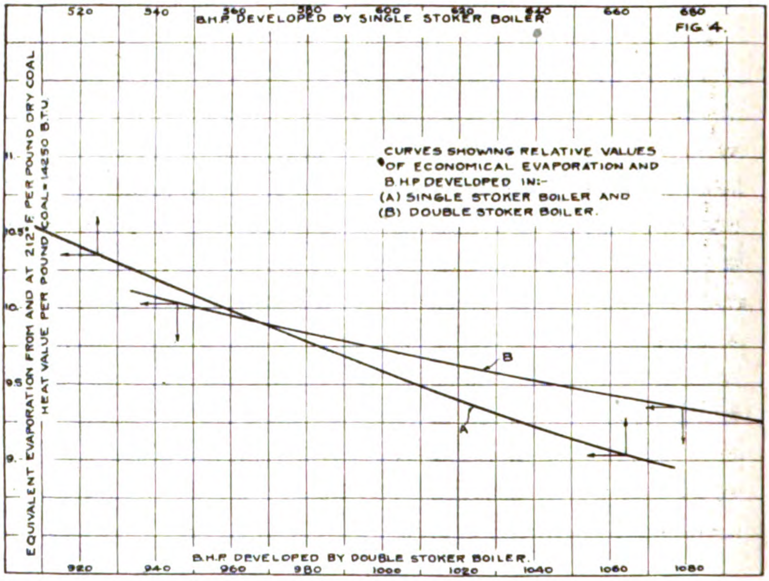
boiler. The research work of such men as Newton, Péclet, Joule, and Rankine, together with recent investigation, has not, as yet, produced sufficiently definite and authoritative results, which may be used as bases of rational calculation in this regard. Under normal conditions of present boiler-practice, estimates of loss vary from practically zero to as much as 15% fuel economy for an increase of 100% in boiler capacity.

Lately, however, the opinion has been advanced that considerable increase in capacity can, without great sacrifice in economy, be obtained by proportional increase in grate area. This idea is based upon the possibility that combustion and



heat distribution and transfer could be much improved under the new conditions, when in increasing the grate area careful attention is given to details of design most conducive to these features. Other conditions being favorable, and with a belief in the correctness of this theory, a change was made in the design of eighteen of the boiler furnaces in the Fifty-ninth street plant of the Interborough Rapid Transit Company. See Fig. 7. Such a design gave the possibility of operating within the range of the original single-stoker boiler together with the higher range of the double stoker.

The second stoker installed; that is, the one beneath the

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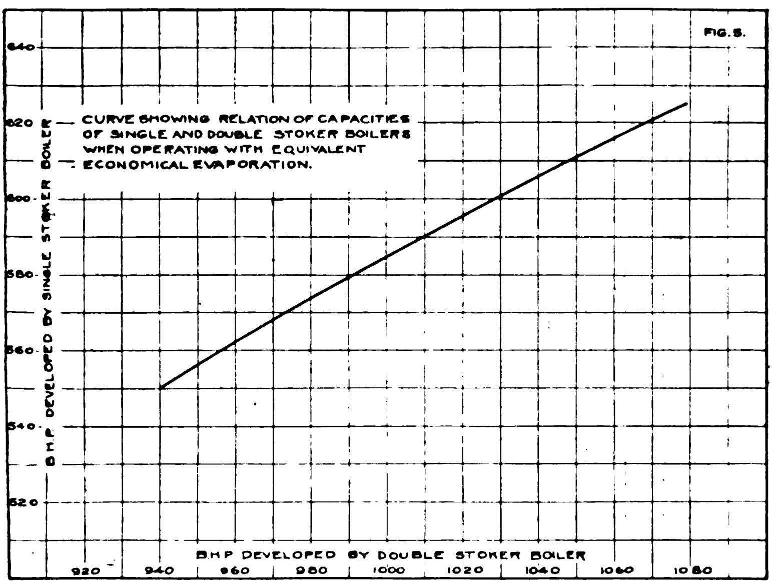
mud-drum as shown in Fig. 7, has an area of 80% of that of the original stoker. Certain features in the construction of the plant prevented installation of a larger size. A detailed description of points in the design are unnecessary, save to call attention to the fact that the lower stoker is constructed practically within a so-called " Dutch oven " and whatever is conducive to good combustion is provided for therein. The curve shown on Fig. 8 is given as corroborating this fact. Operation of these stokers has shown that such is practically done with but little more complication than existed in the single type.

Tests to determine the comparative economical operation of



the double and single stokers show results as given graphically in Figs. 3, 4, 5, and 6. The curves in Figs. 3 and 4 are self-explanatory. Fig. 5 shows a curve plotted upon the values as determined by curves in Fig. 4, this curve being indicative of the fact that operation with the double type was as economical in fuel values, as the single type increased in boiler capacity approximately seventy-one per cent. In the curves in Fig. 6 is shown the fact that the economical loss for an increase in rating of 80%, as proportioned to the increase in grate area, varied between two and three per cent.

To summarize the results of these tests. It has been made

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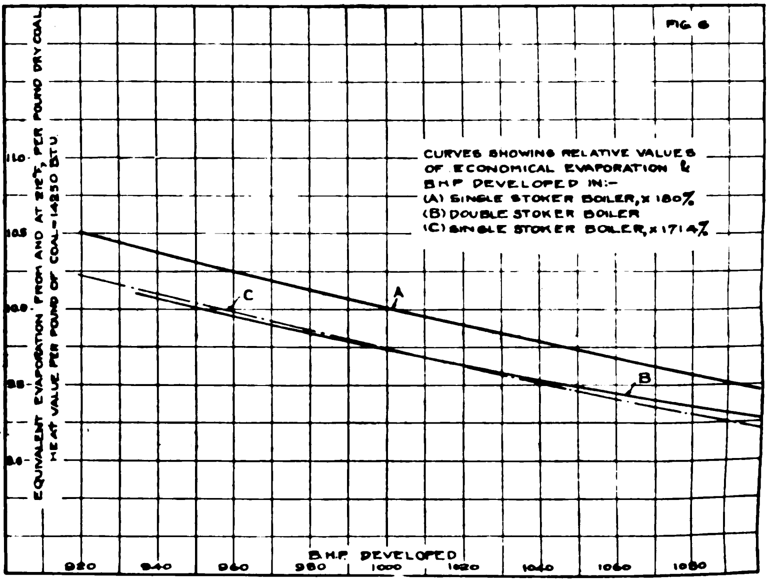
evident that in this particular case double-stoker operation covers the entire range of single-stoker operation and adds an increase of capacity proportionate to its larger grate surface with but slight loss in economy; and that the increase of 71% in capacity was accomplished with no loss in economy.

With these results as a basis, let it be assumed that boiler capacity is increased in ratio to increase in grate surface with but little loss of economy. This view might be further strengthened when consideration is taken of the possibilities of economizer practice, the increase in saving, by proper design, being high in ratio to extra cost involved.



To return to the consideration of the items under the power plant whose first cost has been assumed to be $125.00 per kilowatt, the next point is:

Piping. In the case involved, the cost of steam piping between boilers and manifolds, plus boiler-feed piping, plus boiler blow-down piping, has alone been considered. With any change in number of boilers, capacity remaining the same, the cost of piping will vary in the same ratio times a factor due to change in size of pipe.

Coal-handling apparatus. Fixed plant capacity would seem to demand fixed cost of coal-handling apparatus, but the pro-

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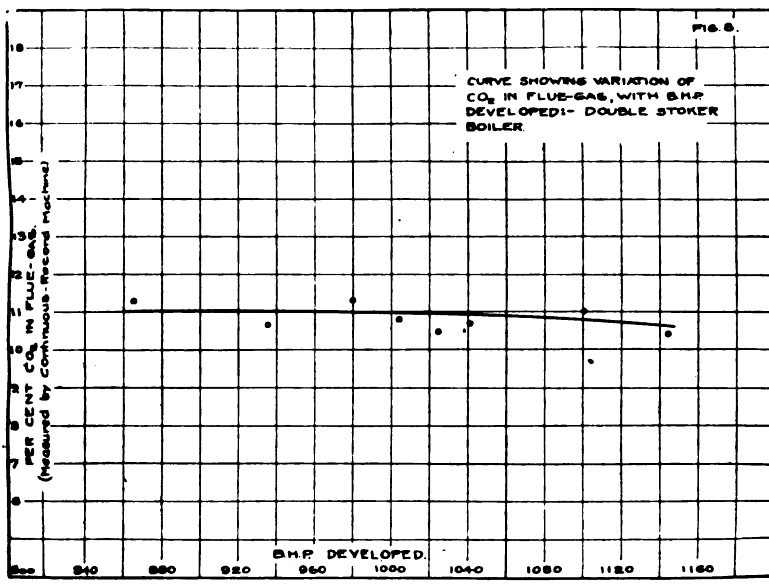
portionate value of the conveying apparatus is so large that when any change is made affecting the length of carry the total system cost will be raised or lowered, although not in direct ratio to such change.

Effect of change of ratio:

$$\frac{\text{heating surface}}{\text{grate surface}}$$

Suppose that in a reconsideration of the plant design, it is decided to cut in half the ratio of heating surface to grate surface by the use of double grates or stokers under boilers of



the same rating. Plant output is to remain the same. A tabulation of the costs as revised would be as follows:

	Per kilowatt
Building (reduced 40%)	$26.25
Boilers (reduced 50%)	3.438
Stokers (remain same)	1.75
Piping (reduced 40%)	3.735
Coal-handling apparatus (reduced 15%)	1.955
Balance (remains same)	64.70
	$101.468

A curve (B Fig, 1) is plotted upon this new basis.

Summation: Plant first cost and fixed charges, each reduced 19.6%.

The next consideration is that of the effect of such changes upon plant maintenance and operation charges. Properly to discuss this, the following tabulation based upon the figures given by Mr. H. G. Stott in his paper on "Power Plant Economics" will furnish a means of comparison:

Maintenance:	Single grate		Double grate
Engine room mechanical	0.64%		0.64%
Boiler room	5.40 – (16%)	=	4.54
Coal- and ash-handling apparatus	0.68		0.68
Electrical apparatus	1.41		1.41
Operation.			
Coal- and ash-handling labor	2.65		2.65
Removal of ashes	1.18		1.18
Dock rental	0.93		0.93
Boiler-room labor	8.38 – (18.5%)	=	6.83
Boiler-room oil, waste, etc	0.21		0.21
Coal	71.94 + (3%)	=	74.10
Water	0.90		0.90
Engine-room mechanical labor	1.70		1.70
Lubrication	0.44		0.44
Waste, etc	0.38		0.38
Electrical labor	3.16		3.16
Total	100.00%		99.75%

The saving in boiler room maintenance and operation may be accounted for in the following itemized statement of boiler-room charges:

Maintenance.	Cost Single grate	Cost Double grate
Boilers	29.5%	14.75%
Economizers	2.78	2.78
Furnaces	17.29	17.29
Stokers and stoker engines	40.68	40.68
Boiler feed-pumps	5.42	5.42
Boiler feed-piping	2.20	1.10
Boiler blow-off piping	0.44	0.44
Water supply piping	1.52	1.52
Total	100.00%	83.98%
Operation.		
Water-tenders	20.82	10.41
Stoker operators	38.09	38.09
Assistant stoker operators	15.49	15.49
Stoker oilers	2.54	2.54

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Economizer oilers and cleaners	5.84	2.92
Boiler feed-pump men	5.08	5.08
Boiler cleaners	10.41	5.21
Miscellaneous labor	1.73	1.73
Total	100.00%	81.47%

Thus with changes as noted, the decrease in maintenance and operation would be 0.25%, the curve for same practically coinciding with Curve C, Fig. 1.

A second set of curves based upon a plant cost of $150.00 per kilowatt as shown in Fig. 2.

Plant cost per kilowatt	$150.00	100%
Building	60.00	40
Boilers	8.25	5.5
Stokers	2.25	1.5
Piping	6.75	4.5
Coal-handling apparatus	2.63	1.75
Balance	70.12	

Same plant double stoker.

Building	(reduced 40%)	$36.00
Boilers	(reduced 50%)	4.13
Stokers	(remain same)	2.25
Piping	(reduced 40%)	4.05
Coal-handling apparatus	(reduced 15%)	2.24
Balance		70.12
Total		118.79

. . . .

Showing a reduction in first cost and fixed charges of 20.8%

Summary. In the case of the $125.00 plant, the following savings might be effected by use of double grate:

First cost, 19.6% saving.

Total plant charges varying from a saving of 5.64% at 100% load-factor to 7.54% at 50% factor to 9.65% at 4.16% factor (365 hours per year).

In the case of the $150.00 plant,

First cost, 20.8% saving.

Total plant charges vary from about 7.06% saving at 100% load-factor, to 9.26% at 50% factor to 11.51 at 4.16% factor.

Thus summarized, the remarkable effect that the grate area and heating surface ratio, when furnace design is carefully considered, may have upon plant first cost and total annual costs, should certainly place this particular feature well up in the list of subjects for careful investigation, and make it a point of primary and fundamental consideration in advanced design.

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Discussion on "Line Constants and Abnormal Voltages and Currents in High-Potential Transmissions".

(Subject to final revision for the Transactions).

Frank G. Baum (by letter): The writer gave approximate rules for determining the rise in voltage, due to interrupting a given current, at a meeting of the Pacific Coast Transmission Association in 1902 and before the Electrical Congress at St. Louis in 1904. The rule given was,

$$E = 200\,I$$

where I is the actual value of the current in amperes at the time of interruption. This does not exactly agree with the rule given by Mr. Berg. The important fact shown is that the higher the voltage the smaller the excessive strains due to switching, etc. The approximate rule will undoubtedly explain many things happening on lower voltage systems that are charged to lightning, etc.

Surges or resonance occur in any transmission system independently of how the transformers are connected. The statement that certain transformer connections eliminate resonance should be qualified, as it is liable to be wrongly interpreted.

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DISCUSSION ON "THE GROUNDED NEUTRAL," AT NEW YORK, OCTOBER 11, 1907

(*Subject to final revision for the Transactions.*)

Peter Junkersfeld: In November, 1900, the Commonwealth Electric Company of Chicago in one portion of its territory put into commercial service the first extensive system of four-wire, three-phase distribution at 4000–2300 volts. This 60-cycle system was soon installed in all the company's outlying and suburban territory, and has since grown to such an extent that the total length of three-phase or equivalent line of feeders to-day aggregates 525 miles, of which 55 miles is underground, the remainder overhead. The neutral of this 60-cycle system has always been connected solidly to ground.

In May, 1902, the Chicago Edison Company raised the voltage of its three-phase, 25-cycle transmission system from 4500 to 9000 volts, and put into service its first star-wound generator delivering 9000 volts directly to the bus-bars without step-up transformers. This system now aggregates 270 miles of three-conductor cable and is practically all underground, only nine miles being overhead. The neutral of this 25-cycle system has been connected to ground from the beginning. During the last year a part of this system has, however, been connected to ground through resistances. The remainder of the system during the last year and all of the system during the previous four years has been connected solidly to ground.

In June, 1907, the Chicago Edison Company put into commercial service its first 25-cycle underground line operating at 20,000 volts. The transformers were connected in delta at the receiving end and in star at the sending end. The neutral at the latter is connected solidly to ground.

The two companies mentioned above have recently been consolidated into the Commonwealth Edison Company, which thus operates a total of about 800 miles of three-phase overhead and underground lines at pressures of 4,000, 9,000, and 20,000 volts in the various zones and for different purposes, but on all of which the neutral either with or without a resistance is connected to ground. The experience in operating high-tension systems with the neutral grounded has, therefore, been considerable, and the engineering policy on this matter has been definite for several years. The experience, however, in grounding the neutral through a resistance is still somewhat limited. The various steps in this experience and development, and some of the reasons, with the conditions now existing, may be of interest in this discussion.

The 4,000–2,300-volt, four-wire, three-phase system of distribution in the outlying and suburban sections permits standard 2080 to 115–230-volt line transformers, thus giving a single-phase, three-wire lighting and small power service at 115–230 volts. It was felt that such a system of distribution would be unstable and would permit annoying and serious voltage fluc-

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tuations if the neutral of the primary system were not grounded. After considerable discussion the neutral was finally grounded, under the writer's direction, just before the first four-wire, three-phase circuit or feeder was put into service.

Among those who at that time (November, 1900) argued most strongly against the grounding of the neutral but who later, after making some experiments, became one of the most ardent advocates, was Mr. George N. Eastman, who, early in 1901, had occasion to make certain tests which led to a series of very careful investigations at a time when accurate information on this subject was very meagre. Some of the results of these investigations were presented by him in a paper before the Boston convention of the National Electric Light Association in May, 1904. These investigations, with the first few years of actual experience, practically fixed the engineering practice on this particular matter in the two Chicago central station companies, who have, since 1900, continued to develop their three-phase transmission systems with the neutral grounded.

We have no direct comparative experience with an ungrounded system under exactly similar conditions. The results from this grounded system have, however, been very satisfactory. There have been practically no underground cable burn-outs on this 60-cycle system, and comparatively little trouble on pot-heads or on the other overhead construction. The total number of transformer burn-outs from all causes, including lightning, overloading, and defects in the apparatus, during the last two years, has been about 1.4%, and 1.2% of the total number of line transformers in service. The percentage expressed in kilowatt capacity connected has thus far been even less. Similar, four-wire, three-phase systems with grounded neutral have during the last few years been installed in so many cities of the country that this practice has become quite well known. The grounding of the neutral on three-phase systems for general distribution has also become very common, at least in parts of Europe.

The 9,000-volt, 25-cycle transmission system in Chicago is used exclusively for transmission to sub-stations, not for general distribution. With the exception of a few induction motor driven exciters, all equipment consists of synchronous converters or synchronous motor-generators.

The present total continuous capacity of the two principal and two subsidiary generating stations is about 110,000 kw. The neutral of the 25-cycle, 9,000-volt system is, however, grounded directly only in the Harrison street and the Fisk street stations. The latter at present contains ten turbo-generator units, the first four of which were originally rated at 5,000 kw. and the last six at 9,000 kw. each, with the usual overload guarantee. The transmission lines from the two stations are operated normally as "radial" systems; that is,

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outgoing lines are independent of each other and are not tied together at the sub-station ends.

The neutral of this system was connected solidly to ground in May, 1902, when the first 9,000-volt generators were started at the Harrison street station. Since the Fisk street station was put in service, the transmission system has at times been operated all in multiple; at the other times, sectionalized. In the latter case each part or section of the system had a grounded neutral so as to avoid having two non-synchronous sections without a grounded neutral on each. At present, and during a large part of the last year, the entire 25-cycle system has been operated in two approximately equal sections, designated "System A" and "System B." Previously to this time the Fisk street station contained but four turbo-generator units, to which have since been added six units of a larger type with slightly different characteristics. Partly for this reason, and partly for the reason that with the rapidly increasing generating capacity it might be well to limit, in case of accidents, the possible flow of current to ground, there was installed a 0.5-ohm resistance between the neutral of each of the four new generators and ground. The four older generators are left with the neutral grounded solidly on each. Normally, the two sets of generators are operated on separate sections of the system, one of which was thus operated with, and the other without, a resistance in the neutral.

During the previous four years, or since May, 1902, the neutral had always been grounded solidly, and with satisfactory results. In case of a cable breakdown between conductors and ground, each cable was usually disconnected from the bus-bars by the overhead relays and oil-switch before the remaining two conductors became involved, thus permitting a quick and accurate location test by the Murray loop method. As the generating capacity of the system increased, and as it became necessary to have heavier overload and longer time-limit setting of relays on outgoing lines, the destructive effects of cable breakdowns have apparently been somewhat greater, although this may be due in part to the very heavy setting of relays. This indicated the desirability of limiting in some manner the current flow in case of accidents to decrease the destructive effects. It was also desirable to secure some comparative data on this matter of resistance or no resistance.

Four possibilities naturally presented themselves: 1, the design of generators with a lower short-circuit current; 2, grounding the neutral on only one of the groups of generators running in parallel, leaving the neutral open on the remainder so as to limit the flow of current to ground to the short-circuit current of the one generator; 3, the introduction of one large resistance between the neutral bus-bar from a group of generators and ground; 4, the introduction of a separate resistance between the neutral of each generator and ground. Partly for reasons previously stated, the latter method was adopted.

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Both of the first two methods mean holding the neutral where it belongs, while both of the last two methods will cause displacement of the neutral with attendant rises in potential, as has been pointed out in Mr. Lincoln's paper.

In four cases of trouble, each affecting from 10 to 30% of the total service at the time, during the two years before the installation of resistances, and during the one year since, the effects might or might not have been modified if the neutral had been grounded with instead of without a resistance. In all the other cases of trouble during this period, and in most of the cases during the three years previously, the use of a resistance in the neutral would probably not have effected any improvement. In most instances the overload relays on feeder oil-switches were set at 100% overload for six seconds, although in some cases they were set at 100% for three seconds. The generator switches are all non-automatic and are opened only by the switchboard operator.

During the last five and one-half years, even after eliminating all cases of trouble which have no bearing on this subject of the grounded neutral, in addition to the four serious cases above mentioned, there have been quite a number of minor cases which have a strong bearing on the matter of the grounded neutral. Especially is this true of cable troubles which, during the last three years, have averaged only two cases per one hundred miles per year. This includes all troubles on 9,000-volt cables from known or unknown causes, except those due to external injury to the lead sheaths.

Notwithstanding these results, we have started some investigations with the oscillograph, and have also installed for purposes of observation some spark-gaps at different points on the system, all with special reference to securing more accurate information for guidance in the development of the 20,000-volt underground system into suburban districts. These investigations have not yet progressed sufficiently to afford much definite information. There are some indications that in the Fisk street station the spark gap when set for 100% above normal, discharges occasionally when the oil-switch on the distance substation end of the line is opened. This instantaneous rise of potential occurs even with the neutral grounded, and may be due to the stored energy of the line. We have thus far not been able to find rises of potential coincident with any other switching or other operation.

Our investigation and experience with one system for five years, and another system for seven years, leads us to believe, that between operating with the neutral grounded or not grounded under our conditions, the grounding of the neutral is the better policy. As to whether or not any additional benefits would be secured by grounding the neutral through a resistance, we feel that our experience is still too limited.

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Philip Torchio: The papers presented by Mr. Rhodes and Mr. Clark give the experience of two moderately high voltage systems operated with grounded neutral. I shall contribute to their discussion the experience of the New York Edison Company's system which is also operated at moderately high voltage, but without grounded neutral. This comparison is not offered in a spirit of criticism of the admirable work described by Mr. Rhodes and Mr. Clark, but as an expression of opinion of those who have not yet found enough evidence of either the desirability or the necessity of grounding the neutral of 6600-volt, high-tension systems operated underground.

The Edison system operates at 6600 volts, three-phase, 25 cycles. The cables are mostly paper insulated, with $\frac{11}{32}$ in. insulation between conductors and $\frac{10}{32}$ in. between each conductor and ground. The feeders are operated on the radial system, not connected in multiple at the sub-stations. The system was started in 1898 with about three miles of high-tension cable, and grew steadily from year to year to the present system of about 200 miles. During the nine years' operation we have had 66 cable troubles of all kinds; of these, 32 developed during operation, and 34 were found either by the periodic insulation test or by inspection of the routes.

Table I gives a summary of all kinds of troubles divided into three classifications. In the first column are the operating troubles proper, cable troubles manifested during operation of the system; in the second column are cable troubles manifested when the cables were out of service, by periodic or special insulation test; the third column shows defective cable troubles found by visual inspection by the line inspectors. It must be noticed that the Edison Company's high-tension cables are distributed over all the city, where a lot of underground work has been done, causing a lot of interference and damage to the cable line. The table shows that there have been, in nine years, 32 operating cable troubles, 14 of which were due to mechanical injury. The majority of the troubles in the rest of the cases were in splices due to defective installation, etc.

If we eliminate the 14 troubles due to mechanical injury, and make allowance for the great amount of interference attendant to the subway conditions under which the New York Edison Company operates, we see that the number of troubles per mile of cable per year compares favorably with Mr. Rhodes' figures for the Interborough system. As to the extent of trouble caused by the cable burn-outs, in no case was the cable subway damage more than nominally.

We have been fortunate up to now in not having a severe blowing up of the subway cables, as mentioned by Mr. Rhodes. In one instance only the cable short-circuit was so severe as to overtax one of the old circuit-breakers—not of standard make—which caused a shutdown of the generating station. The short-circuit was caused by the driving of a pick into one high-tension

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TABLE I

CLASSIFICATION OF ALL HIGH-TENSION CABLE FAULTS FOR THE PERIOD BETWEEN NOVEMBER 14, 1898, AND OCTOBER 8, 1907, INCLUSIVE

Manifested by opening of circuit-breakers during operation	Manifested by low insulation test	Reported by line inspectors
1. In splice	1. In splice	1. Injured in manhole by arc cable burn-out
2. Nail driven into cable (extraneous injury)	2. In splice	2. Nail into cable
3. In sharp bend in manhole	3. In splice	3. Damaged in manhole by alternating-current lighting cables burn-out
4. In damaged sleeve (extraneous injury, cause unknown)	4. In cable (steam exhaust)	4. In cable (extraneous injury)
5. In bend in small manhole	5. Moisture in old rubber splice	5. Damaged by outside parties doing subway work
6. Wet end of cable (extraneous injury due to water leak)	6. Moisture in old rubber splice	6. Damaged by outside parties doing subway work
7. In splice	7. Moisture in old rubber cable (extraneous injury)	7. Damaged by outside parties doing subway work
8. In bend (extraneous injury)	8. Nail driven into top conductor (extraneous injury)	8. Burn-out Fortieth street manhole, injury from adjacent cables
9. In bend—defective	9. In cable (steam leak)	9. Armor damaged by adjacent burning cables
10. In cable (possibly extraneous)	10. In splice (steam leak)	10. Armor damaged by adjacent alternating current burning cables
11. In splice	11. In defective splice	11. Armor damaged by adjacent burning cables
12. Drill forced through tile duct into cable (extraneous injury)	12. In cable (steam leak)	12. Armor damaged by adjacent burning cables
13. In splice (extraneous injury)	13. At splice end	13. In cable, damaged by adjacent burning cables
14. In splice (extraneous injury due to water leak)	14. At splice	14. Splice damaged by adjacent burning cables
15. In cable		15. Punctured splice probably due to surges
16. In splice		16. Damaged by outside parties doing subway work
17. In cable		17. Damaged by adjacent burning cables
18. In splice		18. Damaged by outside parties doing subway work
19. In cable (extraneous injury)		19. Damaged by outside parties doing subway work
20. Crowbar driven into cable (extraneous injury)		20. Damaged while doing excavation work
21. Puncture in straight section of cable (connected with station trouble)		

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Manifested by opening of circuit-breakers during operation	Manifested by low insulation test	Reported by line inspectors
22. Ground detector acted in conjunction. Drill forced through tile duct into cable (extraneous injury)		
23. Ground detector acted in conjunction. Moisture in straight cable due to extraneous injury		
24. Ground detector acted in conjunction. Moisture in straight cable due to extraneous injury)		
25. Defective splice		
26. In easy bend in cable—connected with station trouble		
27. Defective splice		
28. Burns and mechanical injury to cable		
29. Damaged by adjacent burning low-tension cables		
30. Ground detector acted in conjunction. Defective cable in duct		
31. Defective splice connected with operating trouble		
32. Ground detector acted in conjunction. In straight cable—connected with station trouble		
14 Mechanical injury 8 At or in splice 4 In bends in manholes 6 In cables	5 Mechanical injury 9 At or in splice	19 Mechanical injury 1 At or in splice
32 Total	14 Total	20 Total

RECAPITULATION

38 Mechanical injuries
18 At or in splices
4 In bends
6 In cables

66 Grand total.

cable in proximity to the generating station. In other cases the relays and oil-switches cleared the short-circuited cable without affecting appreciably the bus-bar voltage.

Mainly on account of the large storage-batteries on the low-tension system, the effects of cable troubles have been considerably minimized. For the last three years all the cable troubles lowered the distributing voltage an average of 5% for 45% of the total system load with a total elapsed time of reduced pressure of 2.5 minutes. I omit other data corroborative of the general good results of the operation of this system and its freedom from violent disturbances due to cable burn-outs. Furthermore, in every instance when we had a burn-out or dis-

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turbance of any kind, we fully investigated all attendant circumstances and tried to figure out how the results might have been modified by having the neutral grounded. In no case of cable burn-outs did we find that the results might have been sensibly improved by the presence of the grounded neutral. On the other hand, station and sub-station troubles, which are usually minor but considerably more numerous than cable troubles, would in some cases have been made very serious by the presence of the grounded neutral. In the papers presented by Messrs. Rhodes and Clark no mention is made of these troubles inside the stations. But I think that they have an important bearing on the subject, and in most of the plants would weigh very heavily against the adoption of a grounded neutral without resistance, or with low resistance allowing ground currents considerably in excess of the condenser capacity current of the system.

Aside from these practical experiences, there is the theoretical side of the matter, which has been very ably treated by several prominent engineers in this country and abroad.* But unfortunately we know very little of the direct bearing of the theories applied to the operation of the underground systems now under consideration. And in this connection I want to make clear that none of the experiences with grounded neutral given here to-night claims that the grounded neutral, *per se*, will prevent violent surges on the system when under the provocation of a heavy two-wire short-circuit; that is, the grounded neutral has been made to assist in making the operation of certain mechanical relays and switches reasonably more positive than they would otherwise be. If for any reason a heavy two-wire short-circuit takes place, the presence of the grounded neutral is ineffective to change the results from those that would take place if the neutral were not grounded. Furthermore, by grounding the neutral without resistance, a dead short-circuit occurs on a cable every time the insulation resistance of the cable is reduced enough to let an appreciable amount of current pass to ground, while without a grounded neutral the operator might have time to disconnect the defective cable from the system before the ground had developed into a short-circuit. Now, the elapsed time between the beginning of the deterioration of the insulation around one conductor and its final dead grounding is usually very long. It may be several minutes, or hours, or days.

* Steinmetz, American Institute Electrical Engineers, 1901; Kennelly, Electrical World and Engineer, 1901; J. D. Nies, Electrical World and Engineer, 1902; Thomas, American Institute Electrical Engineers, 1902; G. N. Eastman, Western Electrician, 1903; G. H. Eastman, Electrical Congress, 1904; David, Societe Int. des Electriciens, 1904; Blondel, Societe Int. des Electriciens, 1905; Brylinski, Societe Int. des Electriciens, 1905; Steinmetz, American Institute Electrical Engineers, 1905; Thomas, American Institute Electrical Engineers, 1905; Patchell, Institution of Electrical Engineers, 1905–1906.

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The speaker and Mr. T. W. Varley have taken advantage of this fact and have developed a device now being applied to the New York Edison system by which it is expected to obtain all the advantages of selecting and disconnecting the defective cable considerably before the condition of a dead ground is reached. The device can be operated on a system with or without grounded neutral. The device takes advantage of the unbalance of condenser capacity current on the cable system when the insulation of any conductor begins to deteriorate.

In Mr. Lincoln's paper there is shown very clearly the condition of an electrostatically balanced system, when there is no faulty insulation to ground; a similar diagram in Fig. 1,

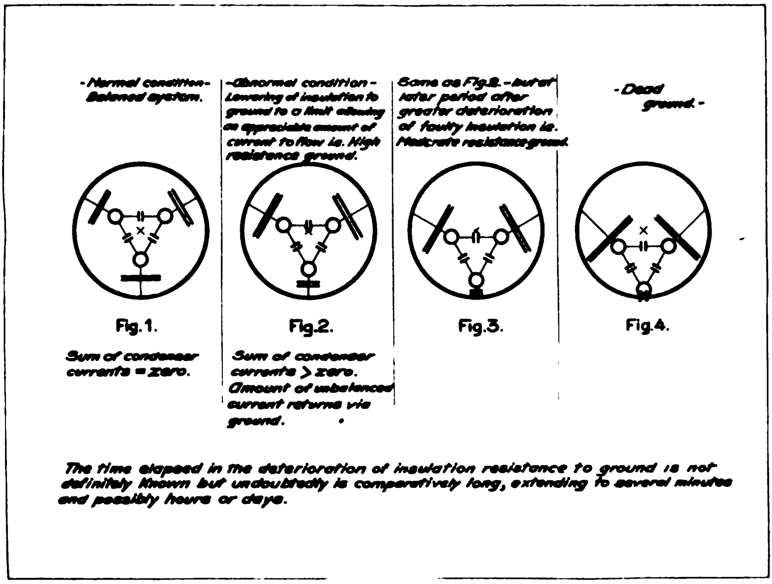

PLATE I

Plate 1, shows approximately the amount of capacity current between conductors, and the condenser current between each conductor and ground. The sum of these condenser currents under normal conditions is zero. If the insulation resistance to ground begins to get lower, and an appreciably small amount of current flows between one conductor and ground, there will be an electrostatic disturbance that will cause the different amounts of condenser current to vary proportionately to the discharge from the conductor to ground as shown in Fig. 2. It should be noted that the sum of the condenser currents is greater than zero, and the amount of unbalanced current would now have to find another path to the bus-bars, and that path is through earth.

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Fig. 3 shows the same condition as Fig. 2, but the resistance to ground is still lower, almost a short-circuit of conductor to ground. Fig. 4 shows the condition of a dead ground, as when all the capacity current of one conductor is discharged to ground.

Referring to Plate II, the device consists of a current trans-

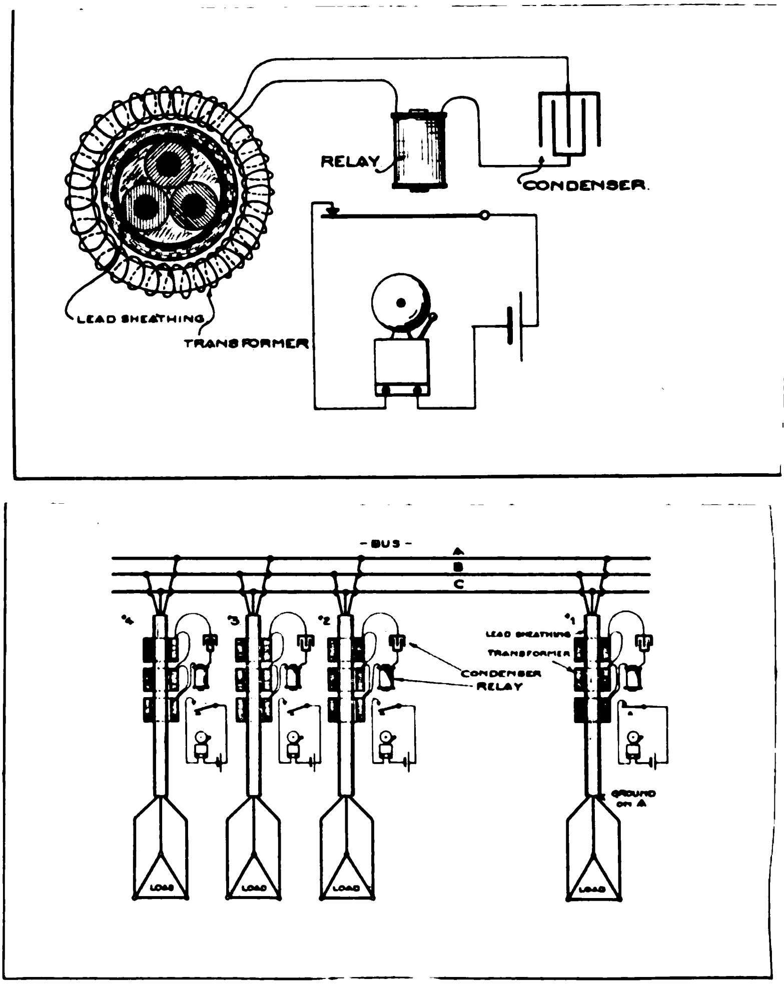

PLATE II

former applied to the lead sheath of each feeder. The secondary of the transformer is connected by means of a condenser to a relay, which is intended to operate either the circuit-breaker or a signal similar to a telephone drop relay of standard make, as desired. This plate shows how the transformers are applied.

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On each feeder we are putting on three of these transformers; they are about 6 in. long, and cover about 18 or 20 in. of the cable.

In Plate III are indicated a set of three-phase bus-bars and four high-tension feeders. The feeders can be extended to any

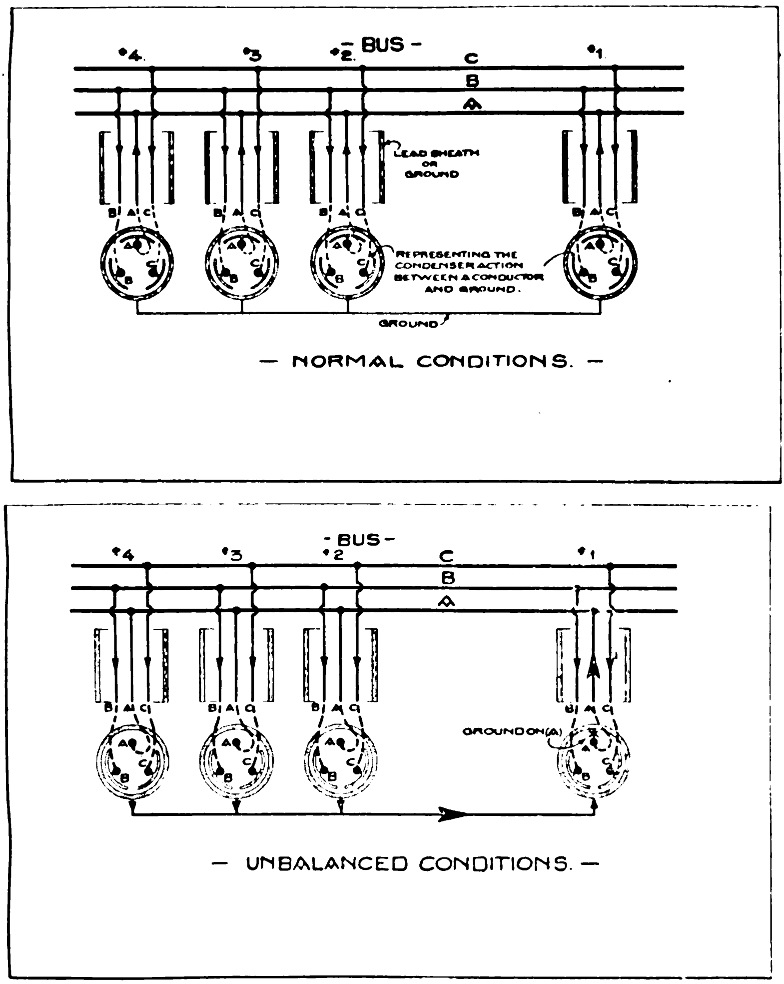

PLATE III

number. The circles indicate diagrammatically the cable, and the segments of circles inside indicate the capacity current to ground of each conductor; and they are made equal, which indicates that the capacity currents in each cable are balanced and no current flows through the earth. The conditions of un-

balanced capacity current as illustrated in Plate I, Figs. 2, 3, and 4 are covered by the arrangement of the devices shown in Plate III. When there is a dead ground, the condenser current of that wire disappears and the condenser current of the other two wires has grown to twice the size. The return for these unbalanced currents is shown by the arrows via earth to the faulty insulation and the grounded conductor of the defective feeder which takes the unbalanced current of all the other feeders on the system. By applying the relay in proximity to the bus-bars, we detect the sum of the unbalancing of all the feeders. By this means we expect to detect trouble long in advance of the short-circuiting of the feeder which is going to be in trouble, and give plenty of time to the operator to disconnect it from the system. This relay can be operated as well on an ungrounded system as on a grounded system; and even with the grounded system I think it will be a valuable auxiliary, especially if the grounded neutral is made through a high resistance limiting the ground current to a few amperes (in the order of the condenser capacity current of the system to ground) sufficient to discharge the cumulative electrostatic charges, and also hold the ground current as soon as the insulation at any point of the system lowers sufficiently to allow an appreciable flow of cuirent.

N. J. Neall: I have chosen for my part of the subject a few comments on the effect of grounding the neutral with or without resistance, from the lightning protective apparatus standpoint. An analysis of the papers presented to-night shows that one deals with comparatively low-voltage underground service; the other intimates the needs of a high-voltage overhead system. We are not much concerned about the lightning protection for an underground system, for certainly no arrester or arrester scheme between the conductors and the ground will be of great benefit, perhaps of no benefit at all, in the line of the disturbances that have been described to-night. Endeavors have been made to protect across phases; perhaps that is the remaining and only form of protection required for underground service. Lightning protection for high-voltage overhead systems has as much bearing on the selection of a grounded neutral as any other one element of operation. Moreover, the mere benefit of grounding is not the sole consideration in selecting the type of apparatus or the method of operation. For example, in an underground system there are a number of conductors in multiple, so that the elimination of one conductor does not cut out the entire service.

The situation can be looked at from the standpoint of design or manufacture and also the standpoint of operation. Manufacturers, I think, follow rather than lead in the adoption of high-voltage protective apparatus; so that as the contemplated voltages for commercial service get higher, it is very doubtful whether one can obtain arresters as quickly as one can get appar-

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atus suitable for this service. Now, to ground the neutral would throw the arrester ratings into a group which has been already only partly developed. Moreover, the question of insulators for these high voltages is also an important element in the selection of the method of connection. Neither a grounded neutral nor an ungrounded neutral will save the puncturing of insulators by high-voltage strains induced by lightning. I do not refer to direct strokes, but to those concentrated charges that are known to exist on transmission lines and do not seem to be able to pass more than a few hundred feet at most from the point of application. It has been thought in times past that these charges jumped over the insulators, but it often happens that they cause punctures. Now, if a line be grounded, with resistance or without, and the charge just described takes place—discharging over the insulator—a short-circuit follows which might be of sufficient strength to shatter the insulator. If it be an ungrounded system, it might be merely a static discharge of the local condenser current, so to speak, which will not have heat enough and will be so attenuated that it will not cause anything further than a temporary disturbance of that particular part of the line.

A grounded neutral, moreover, does not help lightning-arrester operation. Theoretically, it throws more of a strain on the arrester at the time of operation than if the line were not grounded. The arrester, as Mr. Lincoln has said, can be insulated for a lower voltage and closer adjustment to the normal voltage of the line, but it is a grave question whether that is not offset by the fact that the arrester helps to form at the time it operates a partial short circuit on the system, provided the resistances do not give way under the strains, which is most doubtful.

Another element of line operation that is not helped very much by grounding is the telephone plant. One of the most serious conditions in long-distance transmission at the time of any disturbance is the interruption of telephone service within the transmission system itself.

If a resistance must be used—and there seems to be in certain cases good reason why this has been selected—it seems an easier matter to select a resistance suitable for low voltage than one suitable for high voltage. Those of us who have studied the resistance for lightning protective apparatus know that a resistance of small size, of small cost, of large current-carrying capacity, and current-choking capacity, is a very hard thing to get. The same problem in only a modified way exists in the high-tension system with the grounded neutral. I do not believe it is possible to predict any positive method of operation, but I should say, judging from the progress of the art, that if the apparatus can be made sufficiently insulated to be connected in delta, and lightning-arresters can be found that will operate nicely at that voltage, and proper provision is made for the sectionalizing of the line

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or cross-sectionalizing of the line if it happens to be a parallel circuit, that a minimum of interruption of service can be obtained. If in addition to this the progress of the art of lightning protection will indicate relief from a great deal of these induced disturbances that I have spoken of, and if the promise of electrolytic lightning-arresters can be fulfilled, a great deal that I have just said about lightning protection will be very happily modified.

John B. Taylor: The grounded nuetral with or without resistance must be regarded as a protective device, and for this reason the trend of discussion seems to be similar to discussions on lightning-arresters and choke-coils. Apparatus or devices which become operative only in emergency conditions cannot be subjected to tests that will absolutely determine their value for the emergency condition, hence the reported results of successful operation from plants where the neutral is grounded and also where it is not grounded.

Mr. Lincoln speaks of obtaining a neutral connection from " an auto-transformer connected to proper points of the delta." I have had occasion to make up stable artificial neutral points where no neutral is available on any of the apparatus, but my arrangements could not be described in his terms and I ask Mr. Lincoln to show us a diagram of the arrangement he has in mind.

In discussing the proper value of resistance in the neutral lead, Mr. Lincoln states that this resistance must be such as to pass sufficient current to trip the heaviest circuit-breaker. This requirement appears proper for feeder distribution systems which have already been referred to as " radial feeders," but these should be considered as a special rather than a general case. The general case where it will be found desirable to make use of resistance in the neutral, is a system mainly of underground cables, supplying a number of sub-stations, having two or more cables which are parallel on the sub-station bus-bars as well as on the main station bus-bars. A consideration of this interconnection of cables will readily show that the current flowing to ground at the cable fault will divide according to the resistance of the various branches, part flowing from the main station over the faulty cable which has to be cut out, the rest flowing by way of healthy cables, sub-station bus-bars, and faulty cable from the sub-station end. In general, then, the limited current must be at least twice that at which the circuit-breakers are set, and in addition to this there must be a liberal allowance for combined effects of conductor resistance, resistance at the fault itself, resistance of earth return, and drop in voltage at the generator. This requirement makes it difficult to make an entirely satisfactory application of the neutral resistance to systems that have heavy feeders and at the same time fluctuating load, so that only limited generator capacity may be at times in service, especially in the small hours of the night.

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From the record of cable breaks, in Mr. Rhodes' paper, I have figured out the number of breaks per mile of cable per year. I think it a matter of interest that Mr. Junkersfeld's figures on cable breaks, on a 9000-volt system in Chicago, for 100 miles of cable per year, are very nearly the same. From Mr. Rhodes' figures the number of cases of burn-outs per mile of cable per year are slightly greater since the neutral was grounded. While the purpose of the ground in this plant is to secure selective operation of switches, yet I should look for a reduced number of burn-outs. With the resistance, grounds are more quickly removed, with consequent reduction in time of increased voltage strain on the whole system. Possibly the records do not cover a sufficiently long time to eliminate the element of chance; it is also possible that the increased number of faults since the resistance was installed are due to trouble in the joint, etc., incidental to the installation of a number of miles of new cable.

Mr. Clark's experience with neutral resistance is certainly interesting and I hope that he can give us some more data on the following points. What is the resistance of the plate ground? Why have they not availed themselves, in addition to the plate, of the extensive system of water pipes, etc., which is generally available in the neighborhood of any large generating plant? We have very little data on resistance of circuits with different earth terminals, and if Mr. Clark can advise how much the neutral resistance (given as 6.7 ohms) is increased by the earth resistance at the plate, we shall be indebted to him. I also hope that Mr. Clark will tell us the material of the neutral resistance, as cast-iron heated up to 1000° fahr. will practically double its resistance with corresponding reduction in current allowed to pass.

The assumption that the resistance will pass 1000 amperes, apparently makes no allowance for resistance in the rest of the circuit. Obviously, if conditions were such as to permit the flow of 400 amperes—and this is insufficient to trip the circuit-breakers—the neutral resistance could not be expected to accomplish much under these adjustments. I will ask Mr. Clark to tell us what the circuit-breakers are set at? and whether or not parallel feeders are interconnected at sub-station bus-bars?

I am also interested to know how Mr. Clark distinguishes alternating current shunted into telephone lines from alternating current with the same frequency induced in telephone lines. It is of course quite possible to have this current in telephone lines due either to fall of potential between two points in the earth, or due to induction, and I hope Mr. Clark will give a little more data on the local conditions showing that the alternating currents are due to conduction rather than induction.

Carl Schwartz: On account of the many variables connected with grounding the neutral of a three-phase generating and

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distribution system, a careful study of the individual conditions should govern a decision as to:

1 Whether the neutral should be grounded or not.
2 Whether directly or through resistance, and
3 If resistance be used, its amount and proper connection.

In the system referred to in the following discussion, the neutral is grounded through resistance, but partly owing to the fact that the system has been in operation for a comparatively short time, not very extensive experience has been gained. The only statement which perhaps can be made is that so far no trouble has occurred to reason against the arrangement adopted, nor have objectionable features appeared. There are two power stations, ultimately to contain six units of 5000 kilowatts, 11,000 volts, three-phase, 25 cycles each, and eight sub-stations, one power station with 20,000-kw. capacity, and three sub-stations in operation at the present time.

The neutral ground connections are arranged as follows:

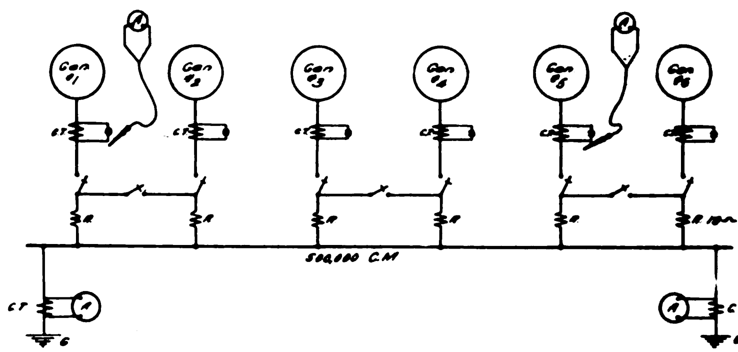

Fig. 1

Fig. 1. A bus-bar of ground potential, 500,000 cir. mils, grounded at both ends, runs through the station. To this are connected the neutrals of the individual machines through separate resistances. Disconnecting knife-switches between machines and resistances allow their separation as may be required.

The ground plates are of copper, about 20 square feet, and buried deep enough to be always under salt water. Current transformers are inserted in each neutral, and also in the ground connection. The secondary leads of the neutral current transformers are brought to the main operating switchboard and ammeters can be inserted in the circuits by means of plugs. For the neutral ground connections, however, the two ammeters are located on a record board in the office of the load dispatcher.

The former instruments are of little importance, while the latter indicate any ground or abnormal condition in the system and are used as "trouble indicators." The neutrals of two

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adjacent generators can be connected together by a tie-switch which is ordinarily kept open, and closed only in case one machine alone is running in a station, as one resistance alone would not allow sufficient current to flow to trip the feeder-switch relays.

The resistances are constructed of cast-iron grids, set in iron frames on porcelain insulators, and enclosed in fireproof brick compartments, with proper ventilation. The resistance of each of them is about 19 ohms, so that with a difference of potential between phases and ground of 6300 volts, about 330 amperes can flow through each resistance. From two to four resistances are to be used in parallel at one time.

There appear to be a few points in favor of the arrangement outlined, as follows:

1. It will be noted that two resistances, equal to about 38 ohms, are always in series between two machines, and experience confirms that practically no cross-current flows between the machines at the time of synchronizing or otherwise. A heavy, 75-cycle, cross-current flows if the neutrals are tied together directly, unless the field current can be adjusted to avoid this condition.

As Mr. Rhodes points out on the third page of his paper, these cross-currents may have a very serious effect on the operation of the station and interfere more or less with synchronizing of the machines. For instance, with a load of 1800 kilowatts on each of two generators, 90 and 160 amperes field current respectively, a cross-current of 130 amperes was observed. With 120 amperes field current on both machines, and 2100 and 600 kilowatts load, respectively, the cross-current was 65 amperes. In both cases the neutrals were tied together solid.

The difference in load in these particular instances was not very large, but the figures indicate the conditions to be expected with a greater difference or with improper field adjustment. This cross-current disappeared entirely with the resistance of 38 ohms inserted.

2. The main bus-bar has ground potential like all resistances and apparatus connected thereto and not in use. This would not always be the case were resistance inserted between the main bus-bar and ground.

3. The arrangement allows the testing of either ground connection; one of these can be opened any time for this purpose.

4. As not all the resistances are required for normal operation, the others serve as a reserve in case of a burn-out.

5. The amount of resistance to be inserted into the neutral ground connection can be sufficiently varied to suit different operating conditions, at the discretion of the operating superintendent.

C. W. Stone: With an ungrounded system a short-circuit is expected to open the feeder-switch. If the neutral of that system were grounded without a resistance, it would contribute

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to the chance of a short-circuit, because one phase to ground means an equivalent to a short-circuit and a consequent shock to the apparatus. It seems advisable, therefore, to put in a resistance to cut down the amount of current existing at this time, and for this reason I have always contended that the resistance should be inserted in the neutral.

In one of the papers it is stated that it seems inadvisable to put in a resistance for each unit, resulting in a variable resistance according to the number of units in service. This is true. But it seems to me that a larger current flowing through the circuit is not serious if there are more machines in circuit, and the relative effect on the system is no greater than if with the single resistance and only one machine.

Mr. Lincoln mentions the different points for grounding a system. I think it a bad plan to ground at more than one place. I know of one case where a lighting system was operated with the ground, not only in the main station, but in different sub-stations, and when a car started up in an outlying district the fluctuation in the lights was serious, due to the flow of direct current on this grounded connection, the neutral being a better ground return than the rails.

If the neutral be grounded on a high-tension system, and an automatic switch be used, three current-transformers will be necessary instead of two—and current-transformers are not the best things to use in a high-tension system.

Mr. Lincoln leaves wide latitude in the selection of the type of resistance. I think that care should be taken in selecting the type of resistance. I note in both of the other papers that iron grids have been used for the neutral resistance. I think this is objectionable, because there is no doubt but that there is a certain amount of reactance with the iron grid. Reactance in series with the condenser action of the cables is not good, as we all know. It therefore seems best to use some resistance with practically no reactance. In the case cited by Mr. Junkersfeld, they carefully avoided the iron grids and put in german-silver ribbon.

F. B. H. Paine: There are places where it is desirable to use a high resistance in the neutral in order to limit the current to a certain small amount, regardless of the amount of energy being sent out, or the number of generators in service. There is no difficulty in operating the main switch with this limited neutral current if a current transformer is placed in the neutral and connected through a relay to operate the main switch with the predetermined current in the neutral.

There is one case where it is desirable that the sub-station neutral at the end of the line be connected to ground through a resistance as well as that of the power station; that is, where this sub-station is connected to the source of power through fuses or other automatic apparatus which may open one leg of the circuit and leave the other legs connected, thus permitting

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the electromotive force of the unconnected wire to soar according to the static capacity of the line, transformer, connections etc. and resulting in injury to the sub-station transformer.

Chas. F. Scott: One point has received but little consideration, and that is the automatic circuit-opening devices. Relays and circuit-breakers have been mentioned, but their importance and their bearing upon the question now under discussion have not been fully brought out. One of the purposes of grounding the neutral is to facilitate the cutting out of a defective circuit. The presence of a permanent ground and the amount of resistance which may be inserted in it for limiting the current when one of the circuit wires becomes grounded are, therefore, very intimately related to the automatic opening devices. These devices are of various kinds. There must first of all be a discriminating, selective instrument which can recognize the conditions under which the circuit should be opened. Such an instrument may act upon overload or upon reverse current and it may incorporate certain time-elements. This device transmits its indication, usually through a relay, to the circuit-breaker. The circuit-breaker should be one which will act instantly and smoothly, cutting out the damaged circuit so quickly that the operation of the other circuits will not be appreciably affected. The action must be practically instantaneous in order to prevent a drop in potential on the system in general, which would affect the running of synchronous apparatus. The opening devices must, therefore, provide for action not only in case of a ground on one wire but also when there is a short-circuit between two of the wires. The whole matter of automatic circuit-opening devices is, therefore, very intimately connected with the grounding of the neutral. This indicates some of the various ramifications of the general problem of grounding the neutral in an operating system.

The discussion this evening confirms an opinion that I expressed some time ago with regard to experience with grounded neutrals. I said that so far as I had been able to determine, the managers of those plants which operate without a ground abhor grounds of all kinds and would not think of purposely grounding any point on the system. On the other hand, others who have operated with a grounded neutral place great reliance for safety and reliability upon the fact that the neutral is grounded, and would not think of operating in any other way.

Paul M. Lincoln: Answering Mr. Taylor's question as to the method of obtaining a neutral in the delta connected system, there is no particular difficulty about this matter. In the absence of a blackboard, if Mr. Taylor will imagine an equilateral triangle as a three-phase system, a conductor at each corner, then the neutral of that system will be at the centre of that triangle. Now, draw a line through the centre and let it intersect the side where it will, and call that line which you

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have drawn through the centre an auto-transformer, with a number of turns proportional to the length between the centre and the points where it intersects the side, that will be the proper connection for an auto-transformer to obtain a neutral. For instance, if one end of the auto-transformer be connected to the middle of one side of an equilateral triangle, and the other end to the opposite corner, so to speak, then the neutral will occur at a tap in the auto-transformer winding such that there is one turn in the section between the tap and the middle of our equilateral triangle to two on the opposite side.

Another point which Mr. Taylor mentioned is that in cases of multiple-connected feeders, a short-circuit occurring at a point near the farther end of these feeders, the ground currents will divide nearly equally between them.

The point is well taken, but is not at variance with the statement in my paper that, " the resistance must be small enough to permit sufficient current to flow to trip the heaviest circuit-breaker on the system ".

Mr. Stone has raised the question as to relative advantages of a resistance in the neutral of each generator as against one resistance for all. So far as the action upon the windings of the generator is concerned, the former is the logical method of operating, because the resistance in neutral of each generator will limit the current which can flow through that particular generator to the point that the resistance is adjusted for. However, that is not the only point to take into consideration when fixing the neutral resistance. Of more importance than the destructive effects on the windings is the damage which will occur at the point of breakdown. Where the current is large, the damage at the point of breakdown is bound to be large, and I believe that limiting the damage at the point of breakdown is one of the great functions of resistance in the grounded neutral. Limitation of damage at the point of breakdown requires a fixed resistance rather than a resistance dependent on the number of generators in circuit.

George I. Rhodes: The object of the neutral resistance is to minimize the effect of a ground and still remove the damaged feeder. With a single rheostat, the possible disturbance to the generating system will be a maximum with one machine running, and a minimum with all generators on the line. With a separate rheostat for each generator, the relative disturbance will be the same at all loads. In either case, the effect will be the same with a single machine on the line, hence a constant resistance will give the better results when more than one generator is running.

In an underground system such as that of the Interborough Rapid Transit Company, a ground on a cable is invariably followed by a short-circuit when the neutral is insulated. I do not see any way in which grounding the neutral can increase the number of short-circuits. In most of our burn-outs since

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grounding the neutral, the switches have opened very easily without evidence of heavy currents.

The inductance of cast-iron grids is very small. Our 6-ohm rheostat has a reactance of about 0.3 ohms at 25 cycles. In view of the large inductance of the generators and transformers on the system, this small increase can have very little influence on resonance effects.

Chas. P. Steinmetz: In the early days of designing high-potential long-distance transmissions, engineers were very careful thoroughly to insulate every part of the system from ground. In later years grounding the neutral was tried, and the results were so satisfactory that the practice found extended acceptance and many engineers since that time have recommended grounding the three-phase neutral. While I do not believe in promiscuous grounding, I recognize that in many cases a great advantage results from grounding the neutral of a three-phase system. It seems to me that the conditions in this respect are about as follows:

1. *The neutral of the three-phase system should not be grounded where grounding is not necessary.* Grounding the neutral introduces the liability of a number of troubles and disadvantages, for any ground on a conductor of a system with the neutral grounded is a short-circuit, and shuts down the system or a part of the system. Theoretically it is true that with one conductor grounded and cut off by some automatic device the three-phase system can be operated with two lines and the grounded neutral as the third. This is called the "inverted three-phase system". But this practice is not always feasible or safe; and just in those cases where grounding is especially desirable to maintain the electrostatic balance of the system, this inverted three-phase system, which is electrostatically unbalanced, would very likely be inoperative—it might lead to high-frequency oscillations and other serious disturbances.

There is an essential difference in this respect between Western long-distance transmission lines and Eastern underground cable systems. Many things that are feasible and safe on a long-distance transmission line would prove disastrous in an underground cable circuit. Where the resistance of the circuit is large, so large that the effect of the resistance is comparable with that of the capacity, as is usually the case in a long-distance transmission line, it frequently is feasible to operate safely with an unbalanced electrostatic condition. It is also feasible to dead ground the neutral, the currents being limited, and oscillations, high-frequency disturbances are damped by the dead resistance. In an underground cable system the problem of keeping down the temperature of the cable, with its poor heat-radiating capacity, limits the resistance of the cable to such values that the resistance effect is practically negligible compared with the capacity effect. In such a case, the damping effect of the circuit resistance is small, the volume of current

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passing over an oscillating arc is large and correspondingly dangerous, and frequently the operation of the system when electrostatically unbalanced is not feasible, or at least unsafe. The experience with such low-resistance cable systems is then quite different from that with high-resistance long-distance transmission lines.

Another difficulty liable to result from grounding the neutral is ground currents, which may reach serious values, flowing over the neutral, especially where several neutrals are grounded, the current flowing between generator neutral and generator neutral, or between transformer neutral and transformer neutral; or, which is usually the most vicious case, between generator neutral and transformer neutral, in the latter case overheating the transformer by excess current even at no load.

Another trouble is that grounding the neutral superimposes upon the pressure difference between ground and line an additional electromotive force, usually of treble frequency, generated in the generators or the transformers. This changes the wave shape of the potential difference between the ground and line, produces a sharp peak, and raises the potential difference of the conductors against the ground by sometimes as much as 40 per cent. and more beyond their normal values. These higher frequency voltages may lead to serious surges or high-voltage oscillations, due to the building up of the voltage by the capacity of the circuit between line and ground being in series with the inductance of transformers or generators in the circuit of these treble-frequency electromotive forces.

Furthermore, telephone disturbances are liable to result from grounding the neutral, electrodynamic induction due to the currents flowing over the ground, or electrostatic induction due to this treble-frequency electromotive force appearing between line and ground. I have known a number of instances where the ground had to be taken off the generator neutral because of telephone interference.

2. *The neutral should be grounded if the system cannot be operated safely when electrostatically unbalanced.* The three-phase system with grounded neutral is electrostatically balanced; that is, all three conductors have equal potential differences against ground. The three-phase system without grounded neutral, in normal condition of operation, is also electrostatically balanced, and the three conductors have equal potential differences against the ground, and the electrostatic relations are the same as in the grounded system. If, however, a ground appears on one of the phases in the ungrounded system, then electrostatic unbalancing occurs and the other two line conductors rise to full potential difference against ground. In this case the grounded system shuts down.

There are two kinds of electrostatic unbalancing by grounding one conductor: first, by a continuous ground or dead ground; secondly, by an intermittent or oscillatory ground, as an arcing

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ground or spark discharge. The electrostatic unbalancing due to the continuous or permanent ground on one phase leads to a higher potential difference between the other two phases and the ground. This may be serious in a system of very high potential, as 100,000 volts. As a rule it would not be serious, but should be well within the margin of insulation safety of an ordinary medium or high-voltage system. The effect of this unbalancing is that lightning-arresters discharge when set close to the normal voltage, so as to afford efficient protection, because during ground they are receiving 73 per cent. more voltage, the full delta voltage instead of the Y voltage. In an ungrounded system, then, the precaution must be taken to arrange a number of additional spark-gaps so that they are automatically thrown into the lightning-arrester circuit, to raise the discharge voltage up to the voltage which in this case exists between line and ground. This can easily be taken care of automatically, as by a fuse shunting these auxiliary spark-gaps, the fuse opening when at the higher voltage the arrester begins to discharge continuously.

There is also to be considered the electrostatic induction from the unbalanced high-potential circuit to lower potential circuits, related to them by step-up or step-down transformers, which may give very serious potential differences; for instance, between the low-potential generator circuit and ground, thus leading to a breakdown in the generator system, or in a primary distribution system, at 2200 volts, fed by the high-potential line. Protective devices are therefore required on these low-potential systems; but aside from this the continuous ground seems to be of minor importance, different from the intermittent or oscillatory ground. The latter leads to serious high-potential, high-frequency disturbances, which may cause rapid destruction. I believe that these are the main causes of the breakdowns in ungrounded underground cable systems where the operation has not been quite successful. Here again is seen the great difference between the high-resistance, long-distance transmission line in which the oscillating discharge over an arcing ground is of very limited volume, due to the high resistance of the line, and the condition in an underground cable system of negligible resistance, where the volume of this high-frequency oscillation is such as to lead to rapid destruction.

In an overhead line this oscillation may finally lead to a permanent ground, while in a cable system it would lead to a short-circuit between the phases. Those arguments against using isolated systems, because such an oscillating arc would lead to a short-circuit between phases, apply only to the underground cable system and not to the overhead line. Where, therefore, such an oscillating ground leads to dangerous results in a high-potential system, it is advisable to ground the neutral.

3. *Wherever it is not necessary to have more than one ground*

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on the system, it is desirable to ground the neutral at one place only. Several grounds are necessary where the circuit extends over so long a distance that the inductance between the ends of the circuit is too large for the ground on one end to safeguard the electrostatic balance against a high-frequency disturbance at the other end of the circuit. In this case both ends of the transmission line must be grounded. Otherwise multiple grounding is undesirable, since it introduces the danger of currents passing over the ground through the neutral, thus leading to electrodynamic induction, as on telephone circuits, to overloading and heating of apparatus by ground currents, and other troubles. Since no apparatus is in circuit at all times, with one ground only some method of switching the ground, or the use of a grounding bus-bar, is necessary to insure one ground being on the system. If it is desired to use the ground as an emergency return circuit, naturally grounds on both ends of the lines are needed, but I do not believe this practice is to be recommended, except for very low power in rather less important lines.

4. *Whenever it is not safe to ground without resistance, resistance should be used in the ground circuit.* Grounding without resistance becomes unsafe in a system of large power, for there would be a severe shock on a system with a grounded neutral if one phase grounds, resulting in a short-circuit. Furthermore, there is the possibility of an electromotive force of treble frequency appearing between the ground and the line, which with a dead-grounded neutral is liable to give rise to serious surges in the system between lines and ground, which are overcome by a resistance in the ground circuit. Therefore, to guard against surges between lines and ground, resistance is desirable in the ground circuit; occasionally it is absolutely necessary. In this case a single resistance is sufficient to dampen and so make harmless an oscillation between lines and ground.

To limit the cross-currents between the grounds of different generators, or generators and transformers, a number of resistances are necessary, one in each generator or transformer neutral. The resistance should be as high as possible so as to produce but little disturbance or shock on the system, and rapidly to damp any oscillation that may arise from a grounded neutral. The resistance should be low enough to act as a ground; that is, to insure a flow of current large enough to open the heaviest circuit-breaker, and thus cut off the damaged part of the system.

Obviously, the resistance should be non-inductive and should be permanent; that is, should withstand excessive overloads, because the current which flows over the resistance in normal operation is insignificant compared with the current which flows in the case of an emergency as a ground on one line. I believe this fairly excludes the use of wire-wound resistances as liable to be inductive, and it also excludes the use of such mixtures

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of clay and graphite as have been mentioned, which are very inconstant in their resistance when exposed to high temperatures and excessive overloads. The requirements, however, seem to point especially to that class of resistances which decrease in resistance with increase of current, the pyro-electrolytes, because such materials would permit the use of a rather high resistance between ground and neutral, thus passing very little current at normal operation; while in case of a short-circuit by a ground on one line, they rise in temperature and decrease in resistance rapidly and then pass a current amply large to open the circuit-breaker and cut out the disabled feeder. That would also give the advantage of introducing a time-limit into the operation of the resistance.

5. I desire to draw attention to a general principle based on human nature, though it has some exceptions. Where the trend of the times is very strong in one direction; for instance, in favor of using induction motors instead of synchronous motors, or vice versa, or grounded neutrals instead of ungrounded neutrals; wherever a case occurs in which it is doubtful whether one should do one thing or the other, it is usually safe to decide against the favored practice, for the reason that no one can remain entirely unbiased in his judgment if the general trend of sentiment is in a certain direction. Where one therefore thinks the advantages about equal, in most cases he unintentionally favors that side which is the fad of the time, and the impartisan argument therefore would be more in favor of the other side.

Frank G. Baum (by letter): The advantages of the grounded star connection over delta for high-voltage transmission (from 60,000 upwards) are as follows:

1. The transformer potential is reduced in the ratio of $\frac{1}{1.732}$ $= \frac{0.58}{1}$, and for very high potentials the transformers may be designed for reinforced insulation on one end of the transformer only, making them safer and cheaper.

2. The maximum potential on all insulators, switches, etc., is 42.2% lower than with delta connection under normal or abnormal conditions.

3. The station wiring is simpler.

4. Small consumers may be supplied with one or two transformers.

A number of years' experience with several large transmission systems operating at voltages from 10,000 to 75,000, both delta and star, demonstrate that where the systems are properly installed there is no more difficulty in operating one than the other. Most of the troubles of the early transmission systems came from lack of insulation; with improvement in insulation

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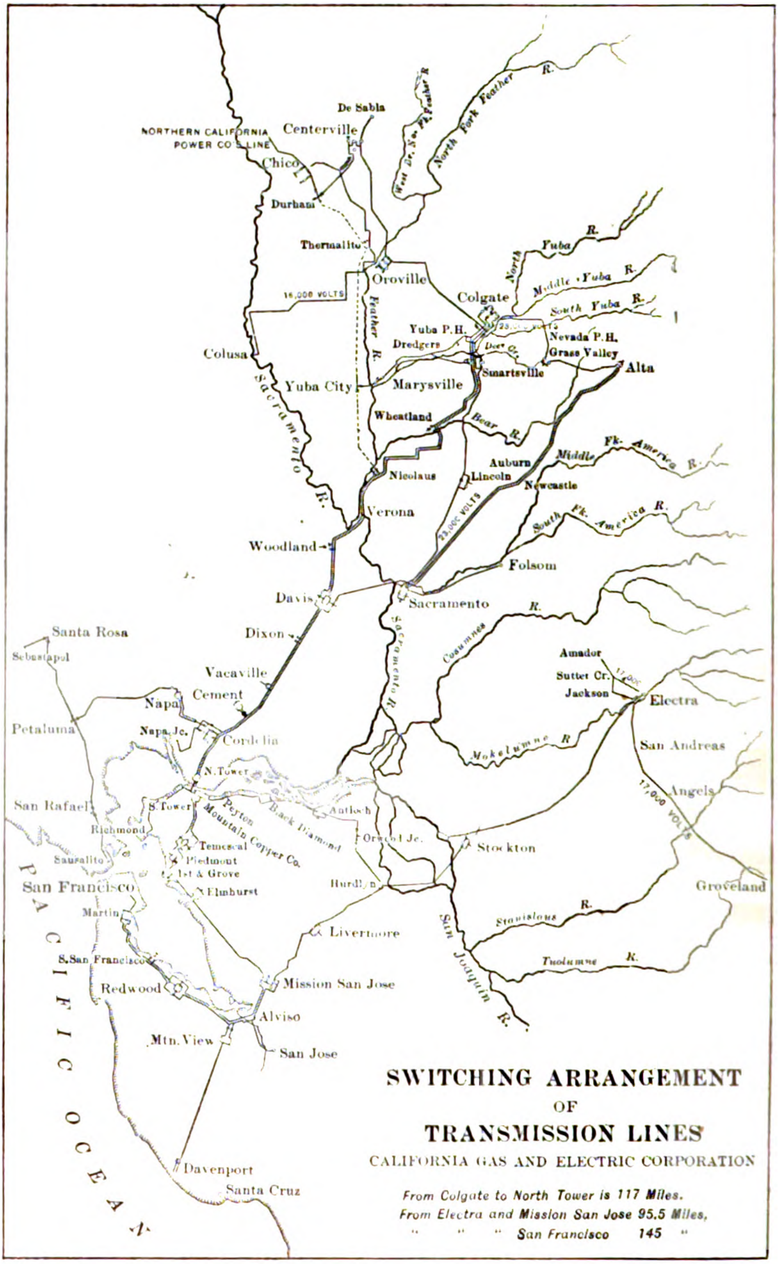

FIG. 1—All lines not otherwise marked are at **60,000 volts.**

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there disappeared nearly all the troubles variously ascribed to "static charges", "lightning", "ground currents". "telephone and telegraphic interference", etc.

Fig. 1 indicates the area covered by the California Gas & Electric Corporation. On this system there are now operating about 75,000 kilowatts in water-power units, and about 30,000 kilowatts in engine units. The generators are star and delta connected, about equally divided. The star-connected generators are not grounded.

Most of the lines are star-connected for 60,000 volts, but other lines are operated delta-connected from the same generators. There are about 1000 miles of circuit at 60,000 volts; 250 miles at 10,000 to 40,000, and 125 miles from 4000 to 10,000 volts. The distributing lines are star or delta, as desired. There are over 100 sub-stations connected to the lines, a great many of them without operators.

The entire system is operated in parallel as a unit, and all the 60,000-volt lines are in parallel. The lines, transformers, etc., are switched in and out of service under any condition of load or short-circuit, and are handled in every respect in switching as though they were 2300-volt lines.

For very high voltage systems I see no reason for adopting anything but a star connection.

O. S. Lyford, Jr. (by letter): This is a subject which has as many sides as there are people interested in it. The grounded neutral is a sort of antitoxin administered, not to prevent initial distemper, but to keep it from spreading. The danger is that the remedy may prove more serious than the disease, or that the handicap to the general elasticity of the system may be greater than the immunity obtained.

When the neutral ground is adopted, its group of evils is accepted as the lesser of two. There is greater flexibility and greater convenience in the use of apparatus if the system is ungrounded. I refer particularly to the use of transformers in delta and the ability to operate with only two of the three. This advantage has led to the use of delta-connected transformers in the great majority of transmission systems, and this grouping of transformers prohibits the use of a neutral ground except by adding more transformers from which a neutral connection may be brought out.

As has been stated, the grounding of the neutral does not decrease the normal working strains or reduce the number of initial disturbances; furthermore, it does not prevent the first surges which may follow an insulation failure. When used, it is generally in the hope that it will minimize the abnormal voltage between line and ground and insure prompt action of the automatic circuit-breakers which will cut off the defective circuit before the damage is extended or the system as a whole shut down.

There are many cases where even the subsequent troubles

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may not be prevented by a grounded neutral. Last year a case in point was reported which affords an illustration with a ludicrous side. A high-voltage line in Montana, having a pole spacing of 200 feet, lost a pole. As a result the wire crossing a cattle ranch hung about four feet from the ground. A steer came along to investigate, put his head over the wire and "got it in the neck" literally. Steer No. 2 came along, took a smell of No. 1 and fell dead. Steer No. 3 smelled of No. 2 with corresponding effect. Nos. 4, 5, etc., did likewise until there were half a dozen or more lying dead in a row.

A grounded neutral would not have reduced the amount of fresh beef materially, for even if the circuit-breakers had opened after each smell the operator would have had no alternative but to close the breaker again, making everything ready for the next. With a long line extending across the country the principal problem is not how quickly can one cut off a defective line, but how quickly can the defect be removed and to what extent can one operate until the defect is removed.

We had one case where one wire of a 15,000-volt three-phase transmission line operating a number of converter sub-stations broke and one end laid on the ground all day without causing any interruption of the service until the next morning when attempt was made to start up the system and it was discovered that only one phase was operative. This would not have been possible with a grounded neutral. We had another case, on the system to which Mr. Clark refers in his paper, where the object of the grounded neutral was defeated in a very fortunate way. The poles of the 11,000-volt trunk line of this system are of steel and are carefully grounded. The cross-arms, however, are of wood. In this case lightning struck the line, shattered some of the insulators and at least one of the wires was left lying on the cross-arm. The current was put back on this circuit and operation continued for some hours until repairs could be made conveniently.

All of this does not prove that the grounded neutral should not be used, but that it is by no means a cure-all; many times it is a positive detriment.

Referring to Mr. Lincoln's list of advantages and disadvantages, there is not much weight to advantages *a*, *b*, and *c*. Although a slight reduction in first cost of equipment may be effected by using weaker insulation, this insulation must be sufficient to resist lightning strains which are greater than any due to a ground on one leg. Static induction in neighboring circuits is seldom a serious matter and can usually be taken care of in some other way. The regular use of the ground as a conductor is a practice that can be adopted in only a certain few instances.

Advantage *d* is the main one, and on the other hand the principal disadvantage, although referred to later in Mr. Lincoln's paper, is not mentioned in the list; namely, the increased

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damage which may result to the generating apparatus and in some instances to the transmission system.

Referring now to the use of a resistance in the ground connection of the system; this is really a compromise. With a neutral dead-grounded, any insulation failure in or near the power house means a practically dead short-circuit on the generators. Such a shock to the system is a serious matter which must be avoided as far as possible. It is inevitable with a short-circuit between phases, but there are few such short-circuits compared with the number of grounds, and one hesitates to adopt a measure which makes these grounds equivalent to short-circuits. The seriousness of these shocks develops, even if the short-circuit is of very short duration. Even fuse-testing in the immediate vicinity of the power station has caused displacement of the generator armature coils. Turbo-generators of high potential are peculiarly vulnerable in this particular.

In the case referred to by Mr. Clark, the neutral ground was adopted principally because of the unusual arrangement of overhead and underground circuits with many possible combinations which may tend to resonance. The object desired was to cut off a defective circuit before such a result should follow. The resistance was placed in the neutral circuit to minimize the shock to the system. This system is laid out with the expectation that there will eventually be 38,000 kw. of generating capacity in the present station, (or possibly double this amount), another power station operating in parallel with this, and a greatly extended underground and overhead transmission system.

As the ultimate conditions are approached, the advantage of limiting the current in the neutral circuit will increase. As matters now stand, the combination of equipment is such that we might expect very satisfactory results with either an ungrounded system, a dead-grounded neutral or a neutral grounded through resistance. There would undoubtedly have been fewer short-circuits, if there had been no neutral ground; on the other hand the character of the protective devices as a whole is such that very few of the interruptions have materially affected the service. As Mr. Clark points out, out of the 70-odd disturbances two would have been handled better with a dead grounded neutral. Neither of these two were very serious, however, and they do not in themselves prove that a change to one of the other combinations is preferable. Damage to the power station equipment by the surges which might occur without a neutral ground or by the shocks which might occur with a dead grounded neutral would result much more seriously.

It is an interesting fact that three of the most important systems, one of which was started without a neutral ground, and two of which were started with neutral dead-grounded, have for different reasons subsequently adopted a neutral ground through a resistance or resistances.

For the general case, it may be said that the ungrounded

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system is preferable, the exception being where there are special conditions which make an interruption of service on a particular circuit of less importance than the consequences if the defective circuit is not immediately cut off. If the system is a large one and conditions necessitate a neutral ground, present experience indicates that there should be a resistance in the neutral circuit.

George I. Rhodes (by letter): There were one or two questions asked during the discussion which I did not care to answer without looking further into the facts.

Mr. Torchio remarked that no mention whatever was made of troubles inside the power and sub-stations which were increased by, or the result of, the grounded neutral. The reason for the apparent omission is that there have been absolutely no station troubles which would not have occurred with equally bad results had the neutral of the system been insulated.

The only possible station troubles that can be increased or affected in any way by the presence of the grounded neutral are grounds on the station bus-bars, wiring, or transformers. Let us consider the effect of a ground on the power station bus-bar under the conditions of operation described in the writer's paper. If but a single generator is in operation, the station will be shut down. If more than one is on the line, that machine whose neutral is grounded will be removed from service, the remaining generators carrying the load. Even with but two generators in operation the remaining machine can easily carry the 100% overload for the short time necessary to get another machine into service. After changing over to the auxiliary bus-bar, the neutral of one machine can again be grounded and condition of normal operation resumed without interruption of service.

With a ground on the sub-station bus-bar, the sub-station will be shut down if the total current required to operate the relays is less than the maximum possible current to ground. If the relays require more current than this, the sub-station will continue in operation, but the generator whose neutral is grounded may be shut down. If a ground occurs on the sub-station bus-bar when the neutral is insulated, it will be impossible to remove this ground without first shutting down the sub-station on account of the large current flowing to ground (about 160 amperes).

It is to be seen, then, that with the neutral grounded, grounds in the power and sub-stations may seriously affect the continuity of service only when a single generator is running.

Mr. Taylor called attention to the fact that since the neutral of the system has been grounded, the burn-outs per year per mile of cable have been more frequent than before. He suggested that perhaps this was due to the large amount of new cable installed. This is undoubtedly true to a certain extent, but it must be remembered that the amount of new cable in the original installation was almost as great. He also suggested

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that the time was so short that the element of chance was not removed. I fully agree with this.

However, I have made a further study of the burn-outs occurring before and after the grounding of the neutral. In the original paper the writer gave a number of distinct operating burn-outs—12 before grounding and 16 after. Of these, there are known to be due directly to severe external mechanical injury, one before grounding, and seven since. Eliminating the latter, there are left 11 burn-outs before the grounding, and 9 after, which were due to internal causes. The writer believes that these burn-outs alone should be used in determining whether or not grounding the neutral has increased the number. Previous to grounding there were operated approximately 620 year-miles of cable, and since then there have been 660 year-miles. This gives the burn-outs per year per mile of cable due to internal causes 0.18 before, and 0.14 since the grounding. It thus appears that the grounded neutral has actually reduced the number of burn-outs that are not traceable directly to mechanical injury.

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